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The impact of emotional arousal on learning in virtual environments

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THESIS

THE IMPACT OF EMOTIONAL AROUSAL ON LEARNING IN VIRTUAL ENVIRONMENTS

by

Stephen O. Ulate

September 2002

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Research on animals has shown that injections of adrenalin paired with a learning experience improved memory retention. Adrenalin is a key hormone in emotional arousal and fight or flight responses. It stands to reason that emotional arousal (in moderation) may also have a positive impact on human learning. The purpose of this thesis was to investigate the impact of emotional arousal on learning in virtual environments. An experiment was conducted to observe learning differences in a low-arousal condition and a high-arousal condition. A first-person shooter videogame (America's Army: Operations) was used as the virtual environment. In the low-arousal condition, participants wandered peacefully through a scenario memorizing objects they encountered. High-arousal participants wandered through the same environment, but were required to fight through the scenario while under attack. Results indicated that individuals in the high-arousal condition performed better on recall tasks immediately following the exposure and also 24 hours later.

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THE IMPACT OF EMOTIONAL AROUSAL ON LEARNING IN VIRTUAL ENVIRONMENTS

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

Research on animals has shown that injections of adrenalin paired with a learning experience improved memory retention. Adrenalin is a key hormone in emotional arousal and fight or flight responses. It stands to reason that emotional arousal (in moderation) may also have a positive impact on human learning. The purpose of this thesis was to investigate the impact of emotional arousal on learning in virtual environments. An experiment was conducted to observe learning differences in a low-arousal condition and a high-arousal condition. A first-person shooter videogame (America's Army: Operations) was used as the virtual environment. In the low-arousal condition, participants wandered peacefully through a scenario memorizing objects they encountered. High-arousal participants wandered through the same environment, but were required to fight through the scenario while under attack. Results indicated that individuals in the high-arousal condition performed better on recall tasks immediately following the exposure and also 24 hours later.

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I. INTRODUCTION

Training is often considered a core component of the United States Armed Forces. Historically, the military has been on the forefront of developing high-end trainers and simulators. However, with the recent revolution in inexpensive computing hardware and software, the military has had to rethink its training methodology. In its efforts to minimize expenditures, the military has either developed programs within the services to evaluate and incorporate commercial off-the-shelf (COTS) hardware and software for use as training tools, or has aligned itself with the private sector to develop new training tools and methods.

For example, in 1999, the Department of Defense and the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM), teamed up with the entertainment industry and established the Institute for Creative Technologies (ICT) at the University of Southern California. In doing so, the military made known its willingness to change its focus from conducting training via traditional methods (e.g., classrooms, simulators, etc.) to the newer, more cost-effective means offered by virtual environment (VE) trainers. ICT has been established to combine entertainment techniques and technology to create synthetic experiences so compelling that participants react as if these experiences are completely real [MACE 00].

With such focus generated by the military on virtual environments as “tools for training”, this thesis investigates the role emotional arousal plays in enhancing

a trainee’s memory for events that occurred during training in a virtual environment.

A. TRAINING IN VIRTUAL ENVIRONMENTS

Military training using instruments that mimic reality can be traced back to the use of simulators built by the Link Company in the late 1920's and 1930's. These trainers looked like sawed-off coffins mounted on a pedestal, and were used to teach instrument flying (See figure 1). The darkness inside the trainer’s cockpit, the realistic readings on the instrument panel, and the motion of the trainer on the pedestal combined to produce a sensation similar to actually flying on instruments at night. The company built 6,271 trainers for the Army and 1,045 for the Navy. In 1945, an AT-6 training airplane cost more that $10 per hour to operate. The Link Trainer cost $.04 cents an hour [KOHA 00]. As opposed to live flight training involving actual aircraft, no pilot was ever injured or killed in the "crash" of a Link Trainer. The Link trainers were very effective tools for their intended purpose, teaching thousands of pilots the night flying skills they needed before and during World War II.

Figure 1. MAPS Air Museum's Link C-3 Trainer
Photo © Gary Haught

Fast forward to today's "computer age" to see how the military's motto of "train like we fight, fight like we train" can be put into action without incurring significant fiscal cost or, more importantly, endangering human life. For example, the Naval Air Warfare Center Training Systems Division (NAWCTSD) is currently developing the Multi-Purpose Supporting Arms Trainer (MultiSAT). The MultiSAT is being designed to provide a joint standardized method for instruction in the employment and techniques of Naval Surface Fire Support (NSFS), tactical air, and field artillery support in expeditionary operations. These are the benefits of such a trainer as seen by NAWCTSD:

> The Joint Forward Air Controller community estimates that operational and maintenance costs could be reduced by 50% by accomplishing many close air support coordination and pilot

proficiency training via a synthetic training environment. Additionally, MultiSAT would reduce the amount of live ordnance required to train forward observers/spotters due to increased proficiency. The ability to provide redundant virtual training will reduce the student "live-fire" training phase. MutiSAT's interoperability capability would provide users a virtual environment to train as an integrated firing team. The enhanced communication training will further sharpen the various firing team skills and reduce the amount of repeated fire missions needed to qualify all members of the firing team. This improved proficiency would directly reduce training time and improve combat readiness throughout DOD [BILB 02].

Another example of the Navy capitalizing on technology can be found in research projects currently funded by the Office of Naval Research (ONR). The development and implementation of systems like these lowers training costs and lessens the possibility of personnel being harmed. On the other hand, having to “run” these simulations repeatedly in order for individuals to gain the desired knowledge and proficiency incurs the unrealized cost of **time** – time which could be better utilized in either a professional or personal situation. The extra time an individual spends in redundant exposures to training simulations can be minimized if the material being taught can be learned more quickly by the trainee.

Training systems in use today often lack the emotional context present in real world environments. These systems are created to minimize costs associated with training (realistically) in the field. Moreover, the designers of such VEs concentrate their efforts on immersing the

trainees by using visually stunning graphics that 1.) depict the actual device/mechanism extremely well, and 2.) implement interactive, 3-dimensional pedagogical agents (see figure 2).

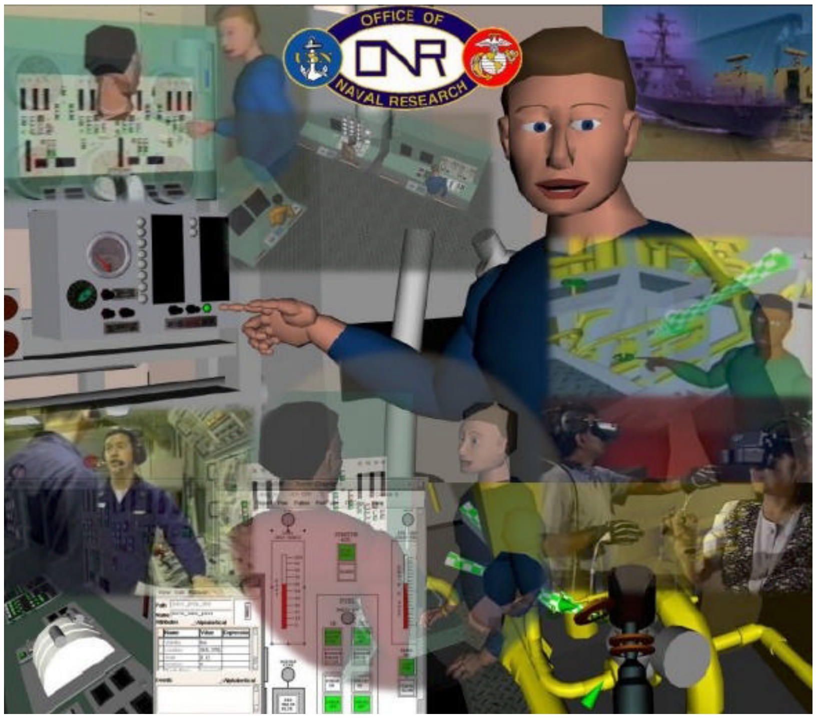

Figure 2. Collage of “Training Studio” software developed by Lockheed Martin [LOCK 99].

The omission of emotional arousal in the design of these VEs may be reducing the effectiveness of the training being conducted. Research using rats, discussed in detail in the next chapter, has shown that emotional arousal (particularly fear) regulates long-term memory storage [CAHI 98, MCGA 96, VIAN 01]. As such, this research investigates the plausibility that emotional arousal (in this case stress) in *humans* could serve as one possible

method for transferring material taught in a virtual environment to long-term memory storage.

B. HUMAN MEMORY AND EMOTION

Briefly, there are three areas of interest with respect to conducting experiments on memory functioning: encoding, retention interval (or consolidation) and retrieval [LOCK 00]. These phases lay the foundation for this research as the experiment presented here attempts to enhance memory by arousing emotion while participants conduct a memorization task in a virtual environment. Emotional arousal is used as the enhancer in this experiment because research suggests its importance in facilitating memory storage. In one of the earliest examples linking emotion and memory, Stratton (1919) described the unusual degree of vividness and detail for memories of emotional events, such as automobile accidents and earthquakes. Referring to hypermnesia[1] for events experienced during a period of emotional excitement, Stratton noted that ‘‘the person recalls in almost photographic detail the total situation at the moment of shock, the expression of face, the words uttered, the position, garments, pattern of carpet, recalls them years after as though they were the experience of yesterday’’ [CAHI 96].

Research has shown that there are many mechanisms in the human body (especially the brain) that regulate emotional arousal and also regulate memory storage. These mechanisms include the amygdala, the hippocampus, the

[1] Exceptionally exact or vivid memory, especially as associated with certain mental illnesses [AMER 00].

endocrine system and their intricate interaction. This group of structures is collectively know as “the limbic loop” and regulates both memory storage and emotion [LEDO 96].

Accordingly, engaging trainees emotionally during virtual environment training sessions could theoretically produce better retention of the material being taught. This research attempts to manipulate the emotional state in individuals in order to enhance the encoding process.

C. RESEARCH OBJECTIVES

The research presented here will focus on tapping this dual role of limbic structures to improve memory retention for training. If it can be determined that inducing stress, a component of emotion, enhances memory, then developers of training systems could incorporate ways to take advantage of those mechanisms to enhance recollection of what is learned in the virtual environment.

In humans, stress is either internal or external and can be either acute (short-term) or chronic (long-term). For the purpose of this experiment, the researcher is attempting to induce the acute, internalized variety. This type of stress is the reaction to an immediate threat, commonly known as the fight or flight response. And because this threat can be any situation that is experienced, even subconsciously or falsely, as a danger, its use here is particularly relevant. Consequently, participants were assigned one of two conditions, either stress or no stress, and subsequently tested to determine which condition recalled more information.

The scenario was set-up in an unreleased level of the PC-based video game America's Army: Operations. In addition to the game offering the researcher state-of-the-art video graphics and sound, the game was developed and designed in-house in the MOVES Institute and could be easily modified for the researcher's needs.

D. THESIS ORGANIZATION

This thesis is organized into the following chapters:

- Chapter I: Introduction. This chapter provides a general outline of the thesis. It discusses the increasing use of virtual environments by the military for the purposes of training. It lays the foundation and motivation behind this research.
- Chapter II: Background. This chapter delves into the extensive research that has been conducted and is currently being performed with respect to memory function and storage, both in humans and in animals.
- Chapter III: Method. This chapter describes the experiment and the two conditions administered to the participants
- Chapter IV: Analysis and Discussion. This chapter contains the results of the experiment in context of the hypothesis and assumptions used in conducting the experiment.
- Chapter V: Conclusions and Recommendations. This chapter provides an overview of the experiment, the conclusions, and recommends future follow-on work in this area of research.
- Appendices:
  - A. Raw Data
  - B. Experiment Protocol
  - C. Consent Forms
  - D. Mission Brief

E. Map of Route
F. Immediate Recall Test
G. Delayed Recall Test

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II. BACKGROUND

A. VIRTUAL ENVIRONMENT TRAINING

The military has historically been at the forefront in developing high-end trainers and simulators. Unfortunately, with the recent revolution in inexpensive computing hardware and software coupled with a reduction in training budgets, the military has had to rethink its training methodology. In doing so, the military has either developed programs within the services to evaluate and incorporate commercial off-the-shelf (COTS) hardware and software for use as training tools, or has aligned itself with the private sector to develop new training tools and methods. As an example of the former, the Chief of Naval Education and Training has launched the Micro-Simulator Systems for Immersive Learning Environments (MiSSILE) with the following initiative:

> "...rapidly identify and apply commercial PC gaming and simulation technologies to the development of selected skills and to encourage and improve tactical thinking. The intent is to improve learning at very low costs by applying the products and economics of the large commercial gaming and simulation market in a learning context. [MICR 02]"

This project will evaluate games that enhance surface and undersea warfare tactical thinking and will explore the use of flight simulation programs for tactics development, situational awareness, and mission planning for undergraduate pilot training and initial rotary wing training.

In regards to the military’s shift in training by aligning itself with the private sector, in 1999, the Department of Defense and the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM), teamed up with the entertainment industry and established the Institute for Creative Technologies (ICT) at the University of Southern California. The ICT was established with the following mandate:

> “...to enlist the resources and talents of the entertainment and game development industries and to work collaboratively with computer scientists to advance the state of immersive training simulation. The goal of the ICT is the creation of the Experience Learning System (ELS), which provides the ability to learn through active, as opposed to passive, systems. In addition to specific military training tasks, the ELS will have applications for a broad range of educational initiatives” [INST 02].

This thesis investigates two particular facets of the “state of immersive training” simulation – memory and emotion. Can these facets be manipulated in virtual training environments? If so, what is the factor or set of factors that should be included, monitored and/or enhanced to ensure a satisfactory product (i.e. well-trained soldiers and sailors)? More to the point, what can be done to or within the virtual environment to enhance the recollection of what is learned during the training session? The experiment presented in this thesis is an observation of the effects on human memory when emotionally aroused.

B. **MEMORY**

In order to lay the foundation for understanding the experiment presented in this thesis, prior research and working definitions for various aspects of memory & emotion will be summarized.

1. Types of Memory

Memory has been studied, researched, classified and categorized by countless varying theories. For the purpose of presenting this thesis' experiment, the researcher will focus on models of memory hypothesized by Endel Tulving.

> In 1972, Tulving introduced to psychologists the distinction between *episodic* and *semantic* memory. An episodic memory is about a specific event that occurred at a particular time and place, such as your memory of getting a traffic ticket or observing a car accident. In contrast, semantic memory is the 'mental thesaurus, organized knowledge a person posses about words and other verbal symbols, their meaning and referents, about relations among them, and about rules, formulas, and algorithms' for manipulating them [BOWE 00].

Table 1 (below) lists characteristics and classifies the concepts of these characteristics as either episodic or semantic (often collectively called "declarative" memory). Of primary concern in this research is the concept of episodic memory. As such, the reader should view the remaining definitions and explanations in this light.

Table 1. Depiction of Tulving's distinction between Memory Types.

Characteristic	Episodic Memory	Semantic Memory
Source	Sensation	Comprehension
Units	Events	Facts, Ideas
Organization	Temporal	Conceptual
Reference	Self	Universe
Registration	Experiential	Symbolic
Temporal	Present	Absent
Affect	More affect	Less affect
Vulnerability	More chance of disruption	Less chance of disruption
Access	Deliberate	Automatic
Queries	Time? Place?	What?
Reports	Remember	Know
Development	Later in life	Early in life
Amnesia	Affected	Unaffected

2. Definition of Memory

Memory has numerous definitions and can be classified into many types. Endel Tulving stated that the term memory can represent a number of different concepts.

> Among the more frequently occurring meanings of 'memory' are (1) memory as a neurocognitive capacity to encode, store, and retrieve information; (2) memory as a hypothetical store in which information is held; (3) memory as the information in that store; (4) memory as some property of that information; (5) memory as a componential process of retrieval of that information; (6) memory as an individual's phenomenal awareness of remembering something [TULV 00].

In general, though, and in keeping within the scope of this thesis, the researcher's working definition of memory is the storing of learned information, and the ability to recall information which has been stored. It has been hypothesized [BOWE 00] that three processes occur in remembering:

1. Perception and registering of a stimulus, or encoding,
2. Temporary maintenance of the perception, or short-term memory, and lasting storage of the perception, or long-term memory, and
3. Retrieval.

These processes are highly correlated with the three accepted phases defined and used in memory experiments: encoding, retention interval (or storage), and retrieval (or test phase) [LOCK 00]. The following sections discuss these processes and phases in detail.

3. Processes of Memory

Memory can be broken down into three basic processes or functions: encoding, short-term or long-term and retrieval (see figure 3).

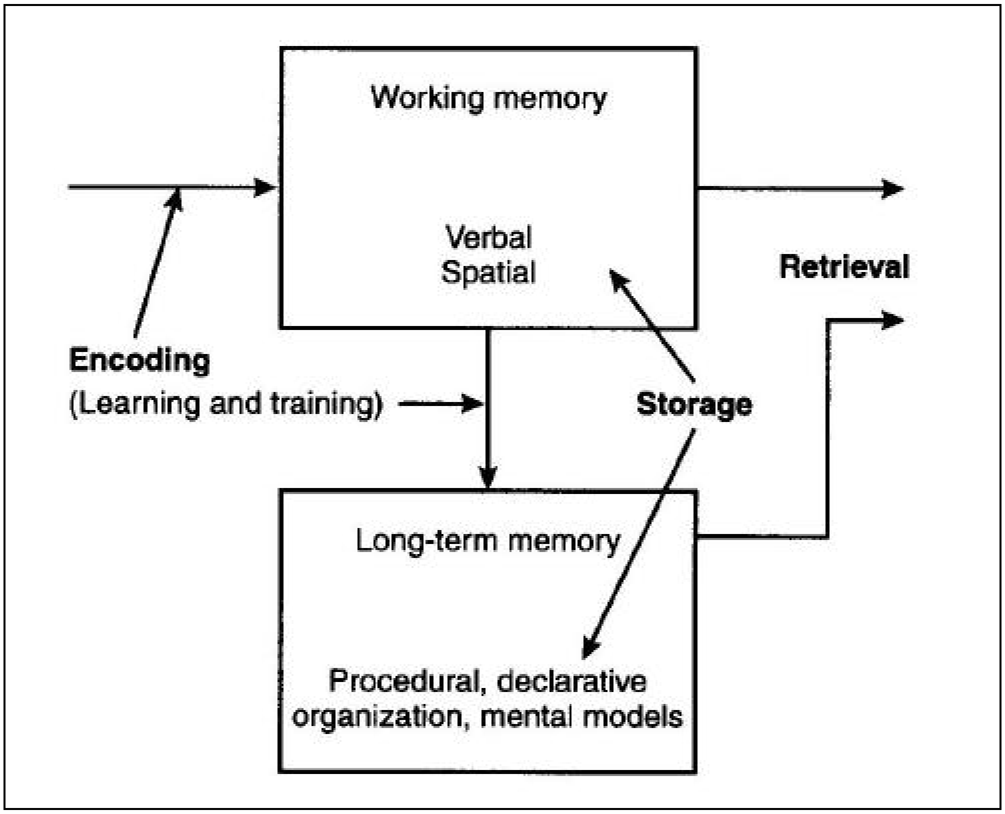

Figure 3. Representation of human memory functions (From: [WICK 00]).

a. *Encoding*

The depiction of this process in figure 3 describes the “placing of things” into a memory system. According to Wickens, this function can take two forms: encoding into working memory, or transferring information from working memory into long-term memory [WICK 00]. The terms he uses in the figure, learning and training, refer to the transfer of information from the short-term store to the long-term store. Learning describes how the information transfer occurs, whereas training refers to explicit, intentional techniques used by designers and teachers to maximize learning efficiency.

b. Storage

(1) Short-term Memory

Short-term memory (often called “working”, “immediate” or “list” memory) is the system used to remember information “in use,” such as a telephone number while one is dialing it. Researchers of short-term memory (STM) form two schools of thought: one proposes a model that utilizes a unitary store to house information [BADD 00], and another proposes a multi-component system that utilizes storage as a part of its function of facilitating complex cognitive activities such as learning, comprehending, and reasoning [BADD 00]. Atkinson and Shiffrin developed a model, known as the modal model, to represent STM.

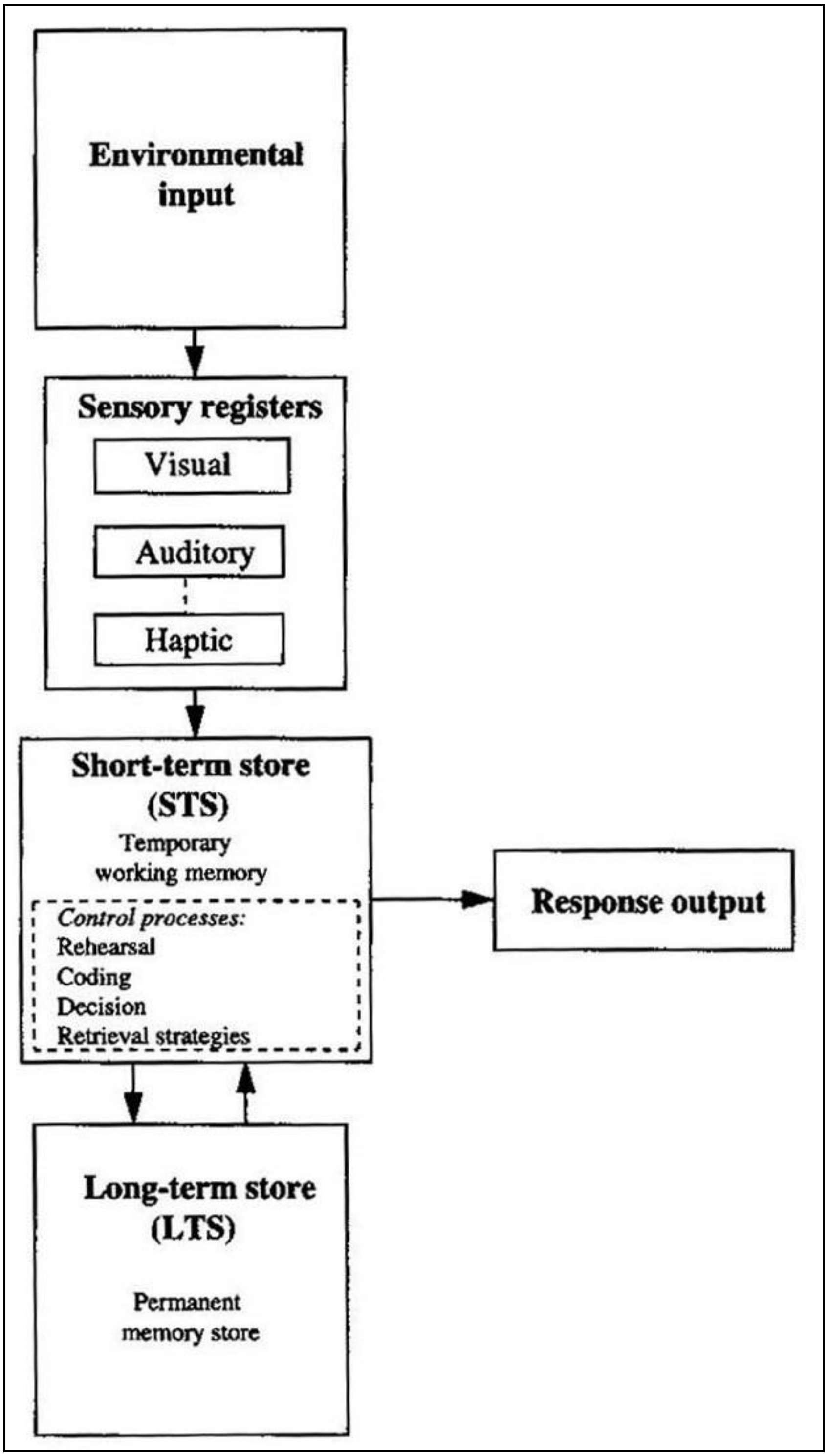

Figure 4. Atkinson & Shiffrin’s (1968) influential model of Short-term Memory (From: [BADD 00]).

The model (figure 4) purports that information comes in from the environment through a parallel series of sensory memory systems into a limited-capacity short-term store (STS), which forms a crucial bottleneck between perception and long-term memory (LTM) or long-term store (LTS). Baddeley and Hitch proposed that the concept of a single unitary STM be replaced by a multi-component system (see figure 5).

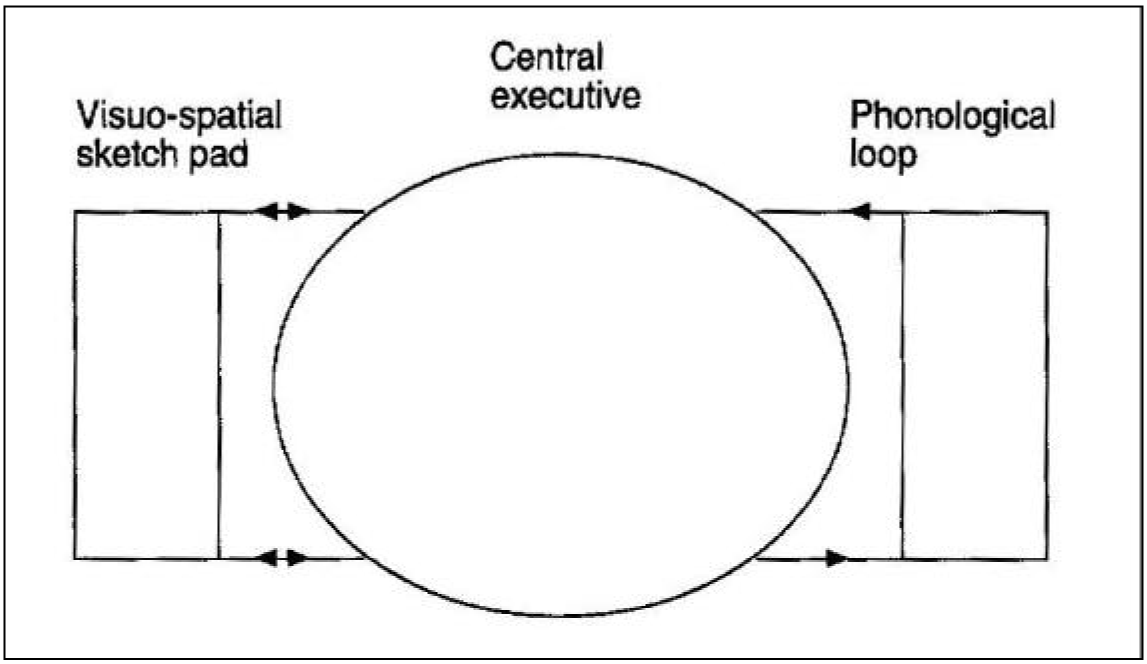

Figure 5. The Working Memory model proposed by Baddeley & Hitch (1974) (From: [BADD 00]).

This system was assumed to be controlled by a limited-capacity attentional system called the central executive. The central executive had two slave subsystems; the phonological loop, concerned with storing acoustic and verbal information, and the visuo-spatial sketchpad, its visual equivalent. Though this latter concept may not be

universally accepted, it does put forth the theory that STM is a complex association of specialized storage systems integrated by some sort of “executive controller.”

(2) Long-term Memory

Long-term memory investigation can be traced back to the work of Hermann Ebbinghaus in 1885. He set out to investigate the formation of novel associations using controlled systematic experiments with careful measurements of his own learning. He eased the problem of measuring memory by studying the rote learning of meaningless material (BOWE 00). He invented the notion of nonsense syllables (like DAX, QEH) because they were meaningless, and the similarity of their content would not differentially affect the process of learning [BOWE 00]. Additionally, he used these nonsense syllables because they were difficult to remember and easy to forget since they had no intrinsic meaning. The task he used on himself is called *serial learning*, an analog of learning the alphabet or learning to put letters in sequence to spell a word: the subject learns to output in a specified order a small set of temporally ordered, discrete items (letters, nonsense syllables, written or spoken words, pictured objects, sentences). However, this approach to human memory has been strongly criticized, notably by Sir Fredric Bartlett in the 1930’s (BADD 97). Bartlett claims Ebbinghaus’ approach ignores the crucial role of meaning in memory. For memory in everyday life is rarely based on rote retention of detail – it relies heavily on remembering the meaning of a passage, a conversation, an event, and/or its context. Consequently, the role of meaning in memory

takes into account the learner's participation as an active organizer of material. For instance, if an individual learns a list of words that happens to contain a number of animal names, he or she will tend to recall the animal names in a cluster, even though he or she originally heard them scattered throughout the list. It is this role of "meaning in memory", or what this researcher previously referred to as mechanisms, that this research tries to exploit.

c. Retrieval

Retrieval, as it pertains to the *processes* of memory, refers to an individual's ability to access (or the process of accessing) information in memory, and not necessarily ***how*** the information is requested. The ***how*** will be discussed in the retrieval subsection of the "Phases of a Memory Experiment" section.

4. Phases of Memory Storage and Retrieval

The three stages of memory storage and retrieval can be described as follows:

a. Encoding

A vast body of memory research has focused on the processing that occurs in the encoding (studying) phase of an experienced event. Various methods exploit the fact that such encoding will be jointly determined by three broad factors: induced cognitive state, task demands, and the nature of the stimulus material [LOCK 00].

(1) Induced cognitive state

There are two prominent examples of this type of factor that are aimed at influencing the encoding process: proactive interference (PI) and manipulation of the current mental state of participant.

(a) Proactive Interference (PI): PI occurs when an activity engaged in prior to encoding the material to be remembered disrupts its retrieval. PI is best illustrated in the verbal studies performed by Keppel and Underwood in which subjects were given a series of three Brown-Peterson[2] trials, one after the other. On each trial they were to recall three consonants after counting backward by threes. What Keppel and Underwood found is that regardless of the retention interval, there was virtually no forgetting on the first trial (see figure 6).

[2] In the 1940's memory loss was widely considered to be the result of new information interfering with previously learned information. In the late 1950's two groups of researchers (one named Brown and a husband and wife team named Peterson) published data that forced a new interpretation of human memory. These researchers developed a memory task in which the participant viewed a trigram of consonants (e.g., GKT, WCH,...) and then performed a number of algebraic computations (e.g., counting backwards by 3's) for less than 20 seconds. The data showed that recall of the trigram was less likely as the participant worked on the algebraic computations for longer durations [LOCK 00].

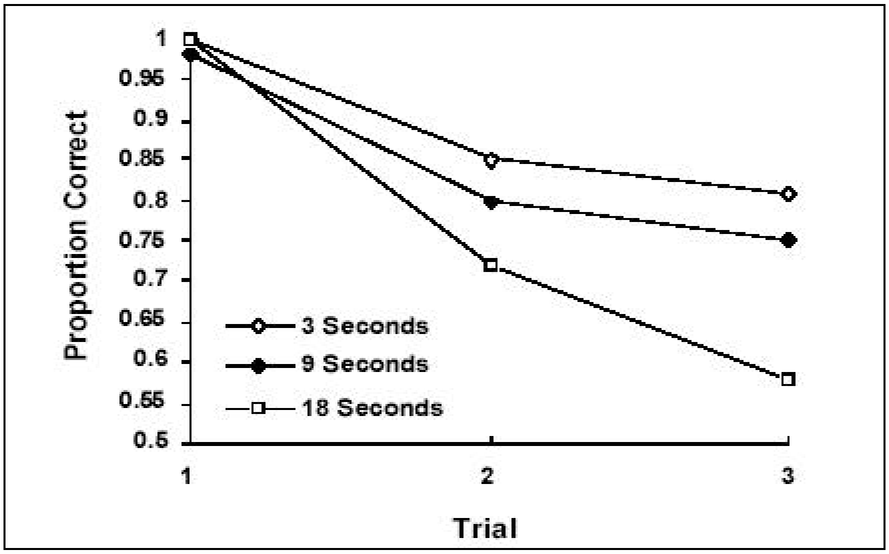

Figure 6. Proportion correct in free recall as a function of the number of trials for retention intervals of 3, 9, and 18 s (from: [KEPP 62]).

Forgetting did occur on later trials, and the level of forgetting increased with longer distracter intervals. Their results can be explained by proactive interference, in which memory for earlier events interferes with memory for later events [KEPP 62]. (Incidentally, interference in the other direction, in which memory for later events interferes with memory for earlier events, is called retroactive interference). The idea is that memory for the consonants presented on Trial 1 interfered with memory for those presented on Trial 2, and so on.

(b) Participant’s Mental State: The other type of factor aimed at influencing the encoding process involves the manipulation of the current mental state. The participant’s mood at the time of encoding has been manipulated through various means, including reading passages, seeing film clips, or listening to music, all aimed at depressing or elating the participant’s mood [EICH

95]. Other experiments have manipulated arousal level, alcohol and marijuana intoxication, and so forth.

(2) Task demands

There are generally two ways of manipulating a participant's task demands in a memory experiment. The intention here is to place a sufficient load on the participant's cognitive ability such that his processing capacity will be reduced. In a typical memory experiment, subjects are instructed to "study" or "attend to" the events they are about to experience for the purpose of a subsequent test of their memory of those events. The nature of this memory test may or may not be explained to the participant. In either case, such instructions (tasks) that warn participants of a future test, often referred to as "intentional" instructions, place a cognitive load on the participant. Another well-known and often used method for manipulating task demands is to require the participant to engage in an independent secondary task while studying the material to be remembered.

(3) Stimulus material

Varying the nature of the material to be remembered has proven to be another factor in the manipulation of the encoding process. A broad distinction has been made between verbal and nonverbal materials, but much finer distinctions have been drawn within these domains. Within the broad class of verbal materials, memory experiments have used digits, letters, words, sentences, paragraphs, and longer prose passages. What's more, various attributes of words have been studied as well: frequency, length, form class, and concrete versus abstract, to name only the most common. In the domain of

nonverbal materials the major areas of research have been memory for pictures, faces, geometric forms, motor skills, odors, and performed actions [LOCK 00]. The breadth and depth of the vast research with respect to stimulus material is not merely to catalogue the properties of the memory systems as they apply to each of these materials, but rather to illuminate a general theory of memory by exploiting the pattern of similarities and differences that are observed as materials are varied.

b. Retention Interval

For this phase of a memory experiment the two major conditions of interest have been the duration of the retention interval and the nature of the events that occur during this interval. The former is straightforward and needs little explanation except to note that formal studies of memory have used retention intervals ranging from zero seconds to at least 50 years [LOCK 00]. Less obvious, and less important with respect to this thesis, are methods concerned with impact of events that occur during this interval. There are generally two such methods: one is aimed at rehearsal prevention and the other is the systematic manipulation of the type of event occurring within the interval. Neither of these conditions factor into the conduct of the experiment of this thesis.

c. Retrieval

This phase can be characterized by the “instructions” the experimenter gives the participants with

respect to remembering (i.e., either an implicit or an explicit remembering task). Implicit tests are those in which memory is revealed in the absence of any instructions to remember, possibly without the subject being aware that a form of remembering has occurred. An example of a test used to investigate implicit memory is word-fragment completion. Subjects are shown a word fragment such as _ r _ c o _ _ l _ and asked to state the word of which it is a fragment (crocodile). Participants would have been previously presented with a list of words with instructions to perform some implicit task, such as judging the word on some attribute. Following the retention interval, participants are given a series of word fragments; some are fragments of words previously shown, others of words not previously shown. The measure of implicit remembering is the degree of superiority of fragment completion for previously presented words over words not previously presented [LOCK 00]. The general idea being that the participant is unaware of the memorizing that is actually taking place (i.e., the participant is led to believe that the task is for some purpose other than the evaluation of memory).

Conversely, explicit tests entail a conscious effort to fulfill the instructional demand to remember. Participants are given clear instructions that they should try to remember the material to be presented. Various explicit memory tests can be characterized in terms of the type and amount of information (retrieval cues) available at the time when retrieval is attempted. Hence two broad categories are used to define explicit memory tests: recognition and recall. In recognition tests, participants

are presented with a replica of the previously presented material so that the experimenter-provided retrieval information can be thought of as a “copy cue” [TULV 83]. Recall tests require the participants to produce information stored in memory. These tests can be divided into three categories: cued, serial, and free recall. Cued recall tests usually involve tasks in which participants are presented with a cue and are then required to recall an item associated with that cue. The cues are described as intra-list cues and extra-list cues. Intra-list cues appear along with the target item during the encoding phase of the experiment, whereas extra-list cues do not.

In serial recall tests, participants are instructed to recall items in the order in which they are presented, whereas in free recall (discussed below) participants are instructed to recall items in any order they choose. An example of the serial recall tests is the classic digit-span test. Participants are asked to read a sequence of numbers and immediately asked to recall the sequence in the same order. Digit span, then, is the maximum list length that can be correctly recalled. There are two phenomena related to this type of recall (and free recall): primacy effect and recency effect. An explanation of these terms is included in the free recall description below.

In a free recall task, following the presentation of a set of discrete experiences, participants are asked to recall them in any order that they choose. If the participants recall attempt is allowed to begin immediately after the material has been presented, then the recall levels will vary according to the serial position of

the item when presented. A frequent finding in free recall (and in serial recall) is that items presented at the beginning (“primacy”) and end (“recency”) are typically recalled earlier and more often than items presented in the middle [OHM 16]. As a performance measure, therefore, the number (or proportion) of items recalled is an aggregation (or averaging) over recall scores that may vary systematically with the serial positioning of the items presented [ohm 130]. The usual interpretation of the recency effect is that the higher recall level of last-presented items reflects the output of the contents of working or short-term memory. Thus, one method of removing the recency effect from the response measure is to delay recall [ohm 50].

C. EMOTION

1. Definition of Emotion

Emotion is the subjective, internal experience (by an individual) of a group of biological reactions arising in response to some situation. For instance, there is an affective response (sadness, anger, joy), a physiological response (changes in internal bodily functioning), a cognitive response (an interpretation of the situation), and possibly a behavioral response (an outward expression). Over the last century, psychologically-based theories have provided influential explanations of how emotional experience is produced. The James-Lange Approach proposes that conscious conclusions about what we are "feeling" form in reaction to physiological changes occurring in the body (see figure 7). The Cannon-Bard Approach proposes that the lower brain initially receives emotion-producing

information and then relays it simultaneously to the higher cortex for interpretation and to the nervous system to trigger physiological responses [LEDO 96] (see figure 7).

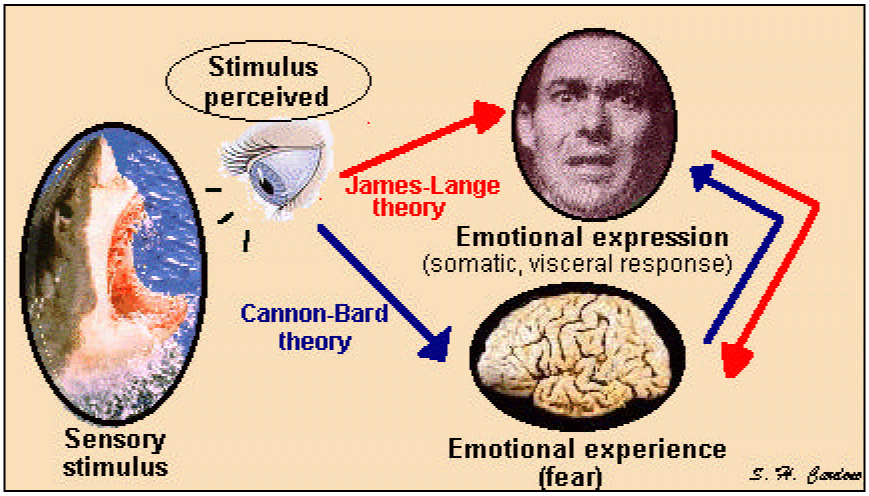

Figure 7. Comparison of the James-Lange and Cannon-Bard theories of emotion (From: [HEAL 02]).

Yet another approach, the Schacher-Singer Approach, gives highest importance to the cognitive skills that create an interpretation of the situation and so provide a framework for the individual's behavioral response [LEDO 96]. In either case, the feeling component of emotion encompasses a vast spectrum of possible responses. Psychologists have attempted to offer general classifications of these responses, and as with the color spectrum, systematically distinguishing between them largely depends on the level of precision desired. One of the most influential classification approaches is Robert Plutchik's eight primary emotions - anger, fear, sadness, disgust, surprise, curiosity, acceptance (trust) and joy [LEDO 96].

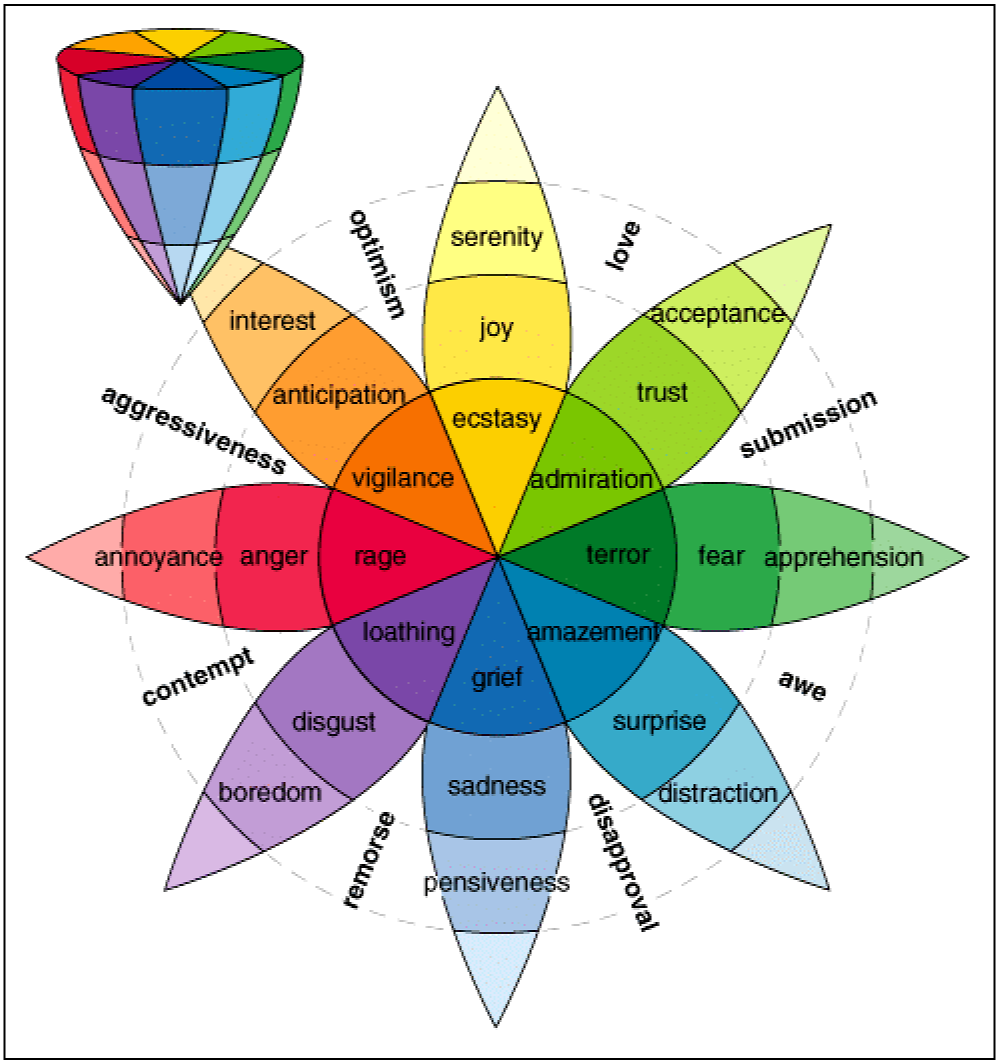

Figure 8. Plutchik's Theory of Basic and Derived Emotions (From: [AMER 02]).

Plutchik argues for the primacy of these emotions by showing each to be the trigger of behavior with a high survival value (i.e. fear: fight or flight). He considers other emotions a consequence of a blending of his eight primary emotions (see figure 8). This research seeks to manipulate these basic emotions and observe their affect on human memory. However, in order to manipulate emotions, we need to look a bit deeper.

Without any doubt, the anatomical structure most clearly related to emotion is the amygdala [LEDO 92]. The amygdala is a small structure in the brain, the size and shape of an almond, situated at the heart of the temporal lobe, which has abundant connections with a great variety of other brain areas. It is the most important component of a network of structures that process emotional information. The function of this structure consists in assigning emotional significance to environmental stimuli, whatever their sensory modality [LEDO 92]. Put more simply, what the amygdala does, when a new stimulus is presented in the subject's sensory field, is to make a quick assessment of it and to tell the rest of the brain if the stimulus represents a danger or, on the contrary, promises some gain. The amygdala is able to make this quick assessment of the stimulus because research in auditory pathways has shown that the sensory thalamus has a direct pathway to it [LEDO 96]. In order to obtain this response from the amygdala, we need a working definition for emotional arousal (stimulus).

2. Emotional Arousal

Emotional arousal is the result of stimulus or perceived stimulus, either internal or external. In virtual environments this is usually accomplished in two ways – visually and aurally. In the real world, the sense of vision is relied upon about 70 percent of the time for perception while hearing (sound) accounts for about 20 percent. The remaining ten percent is distributed among the other sensing modalities [HEIL 92]. Although sound only accounts for 20 percent, its ability to pass

threatening information (real or perceived) to the amygdala has proven to be far quicker than its visual counterpart. As such, the research presented here seeks to take advantage of this fact.

Principally involved in the physiological component of emotional arousal are the autonomic nervous system (ANS) and the limbic system. The ANS regulates individual organ function and homeostasis, and for the most part is not subject to voluntary control. It is also known as the visceral or automatic system.

A far more complex system affecting emotional arousal was under investigation in 1939 by Paul Maclean. He continued previous work by the neuroanatomist James Papez and coined the term “limbic system” to describe an area of the brain that was made up of several regions. The primary brain regions included the hypothalamus, cerebral cortex, the amygdala, septum, the prefrontal cortex, and the hippocampus. This system was born out of the desire to “tell us where emotion is in the brain on the basis of knowing something about the evolution of brain structure” [LEDO 96] and is often considered the center of emotions [HEAL 02]. However, the system definition as a whole has had to endure some weakening in light of recent research. For example, damage to the hippocampus and other regions of the limbic system have relatively little consistent effect on emotional functions but produce pronounced disorders of conscious or declarative memory – the ability to know what you did a few minutes ago and to store that information and retrieve it at some later time and to verbally describe what you remember. These were exactly the kinds of

processes that MacLean proposed that the limbic system would not be involved with [LEDO 96]. Although LeDoux presents this example explaining why the limbic system's stature is waning, he does not account for the interactions innate in a system of this complexity. The limbic system may not stay pure to MacLean's definition, but its components and their inter-system/intra-system interactions certainly play an important role in mediating emotional memories. It's these interactions that are the focus of the next section.

D. EMOTION-MEMORY INTERACTION

Because we are dealing with the complexities of the brain and its systems, many of the interactions mentioned in the previous section take place on a neurobiological level. The leading researchers in this field are James L. McGaugh and Larry Cahill. Their initial studies involving rats suggested that emotion, particularly the chemicals involved in emotional arousal, facilitate the transfer of memory from the short-term to the long-term store by activating the amygdala [MCGA 96]. These studies observed that rats remember better how to proceed through a maze if they are given the stimulant drug adrenaline (also called epinephrine) during a critical period following training. Rats injected with the stimulant prior to the training period or several hours after the training period remembered the maze no better than animals that were given no stimulants at all. The fact that recently formed memories are susceptible to such exogenous modulatory treatments illuminates the potential for endogenous modulation of memory storage for emotional events [CAHI

98]. Accordingly, Cahill suggests that stress hormones are the a *priori* candidate endogenous modulators (see figure 9).

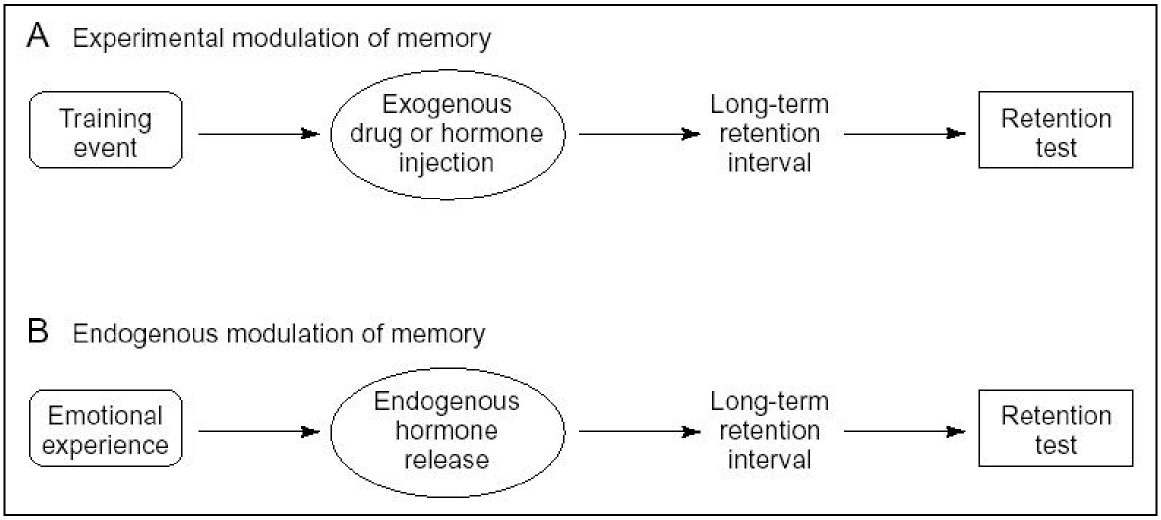

Figure 9. Parallel between (A) experimental (exogenous) modulation of memory and (B) endogenous modulation of memory (From: [CAHI 98]).

Therefore, emotional arousal, in this case stress, tends to serve the immediate adaptive (ANR or limbic) response. Studies involving humans using placebos and the drug propranolol[3] have suggested that the normal memory advantage for the central details of emotional events is a result of the unique involvement of those adrenergic[4] hormones [MCGA 96]. In this study, participants were injected with either propranolol or a placebo before they viewed an emotionally arousing or neutral short story. Strikingly, propranolol

[3] A drug, $C_{16}H_{21}NO_2$, that blocks beta-adrenergic activity, used to treat hypertension, angina pectoris, and cardiac arrhythmia and to prevent migraine headaches [AMER 02].

[4] Activated by or capable of releasing epinephrine or an epinephrine-like substance, especially in the sympathetic nervous system: adrenergic nerve fibers [AMER 00].

attenuated participants' recognition advantage for the central details of the emotional elements while having no effect on their memory for the non-emotional elements (the emotional story contained both arousing and neutral parts). In light of these results and those presented by Cahill, McGaugh has developed a model depicting the endogenous hormones that enhance memory (see figure 10).

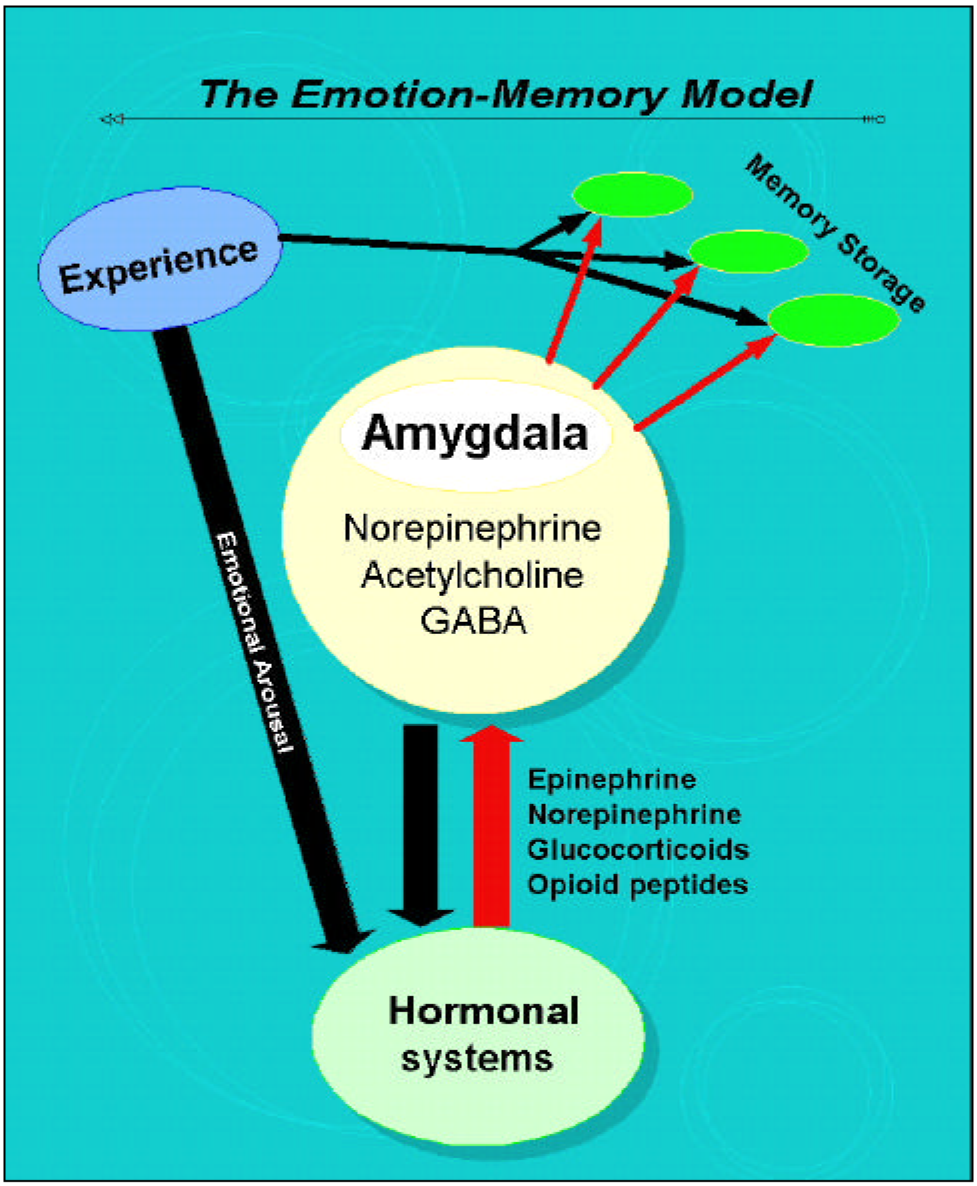

Figure 10. McGaugh's Emotion-Memory Model (From: [MCGA 00])

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III. METHOD

A. EXPERIMENT DESIGN

This thesis will assess the effect of emotional arousal (in this case stress) on encoding and retrieving information learned in a virtual environment (VE). To do this, each participant will find themselves ordered to conduct a mission in a virtual P.O.W. camp environment and be required to memorize various objects placed in four different locations (shacks) throughout the VE (see Appendix H).

Figure 11. Players' view while being attacked. (From: America's Army℠: Operations)

The inducing of stress, by means of contact with an opposing force (see figures 11 & 12), will be the independent variable of this study, while the percentage of correct responses to two subsequent tests will be the primary dependent variable. The participants' correct responses to two different sets of questions will provide an objective measure of that individual's ability to recall what he or she was asked to remember.

B. VIRTUAL ENVIRONMENT SELECTION

Because the underlying assumption of presence in trying to obtain the desired emotional arousal (stress) is central to the experiment, the virtual environment required for this research had to meet three criteria: excellent graphics, state-of-the-art sound quality and contain a never-before-seen (or played) game level. The latter requirement was seen as the most important of the three in that the researcher wanted to minimize, if not altogether eliminate a participants' prior knowledge of the setting in which the memory tasks were to take place, also known as the conditioning effect. Research has shown that memory advantages are gained by individuals who are provided with location and place cues at the time of information acquisition [TAN 01]. Consequently, the researcher chose an as-yet-to-be-released level (called "HQ Raid") of the game America's Army℠: Operations. Additional consideration was given to this game since its development is being done in-house at the Naval Postgraduate School. This proximity allowed the researcher to work closely with the developers in order to manipulate certain variables (e.g. enemy

artificial intelligence (AI) algorithms, weapon fire/hit/miss rate, health of the players, etc.) within the actual code of the game/VE. No other game offered the researcher this level of control.

Yet another important reason for selecting this *particular* VE (and again, in attempting to satisfy the underlying assumption of presence for obtaining the desired emotional arousal) was its similarity to a previous experiment conducted here at the Naval Postgraduate School. Research using a similar VE and, in particular, the same audio configuration demonstrated a significant (positive) effect on participants' sense of presence [SAND 02]. Sanders and Scorgie's research analyzed four different sound delivery methods' effect on presence. They concluded that "the addition of sound to a virtual environment affects the level of presence by inducing arousal in the user" {SAND 02]. As mentioned in Chapter II, the auditory pathway has a direct link to the emotional center, the amygdala, and accordingly, a game had to be chosen that afforded excellent audio reproduction. Again, America's Army^{sm}: Operations was the game of choice. It's incorporation of the latest technology (e.g., EAX 3.0 and Dolby Digital certified) and its use of spatial audio was seen by the researcher as essential for inducing the desired levels of arousal.

Finally was the consideration of graphics (see figures 11 & 12). America's Army^{sm}: Operations has garnered much praise as its superb, realistic graphics (and superior audio) are considered to be among the best currently available of any video game [ACCA 02].

Figure 12. Players' view when being shot (red on the screen for approx. 1/6 of a second) (From: America's Army[sm]: Operations)

C. EXPERIMENTAL DESIGN

The experiment was a between participant design with the presentation of enemies being the independent variable (i.e., participants either encountered enemy [were stressed] or they did not encounter any enemy [were not stressed]). The presentation of enemy (and their programmed aggressiveness) was the method the researcher used to induce stress. Working with the assumption that the participants felt present (that is, they experienced that sense or feeling of "being there"), an attacking enemy

would be perceived as a significant threat. According to LeDoux, the presentation of:

> threatening stimuli causes the pituitary gland to release adrenocorticotropic hormone (ACTH) that results in the release of a steroid hormone from the adrenal gland. The adrenal hormone then travels back to the brain...[and] these hormones help the body deal with the stress. This so-called stress response is ubiquitous amongst mammals, and also occurs in other vertebrates. These bodily responses are not random activities. They each play an important role in the emotional reaction and each functions similarly in diverse animal groups [LEDO 96].

Accordingly, this endogenous release of hormones *is the* sought-after effect in this experiment (see figure 9).

The dependent measure in this experiment was participants' recall score on 2 tests presented after exposure to the memory task in the VE. One test was administered immediately after participants completed their virtual mission, and a different test was administered 24 hours after completion of the exposure to the video game. The participants were asked not to make notes on paper which they might later be able to study, but they were encouraged to use whatever cognitive means they would "normally" use to memorize the objects presented to them during the experiment.

D. EQUIPMENT

The computer used in the experiment was a Pentium® IV, 1.8 GHz computer using a Creative Labs Audigy Sound Card which output the sound to five Genelec 1031A self-powered monitor speakers and a Genelec 1094A Active Subwoofer System in a 5.1 configuration. The graphics were presented

through an NVIDIA Gefore3 graphics card to an NEC MultiSync 18” flat panel LCD monitor (see Appendix I for exact equipment specifications).

E. PARTICIPANTS

A total of thirty (30) participants, ranging in age between 24 and 43, volunteered for this study with a breakdown of twenty-eight (28) males and two (2) females. No monetary compensation was provided. All participants were affiliated with the Naval Postgraduate School either as students, instructors, or employees, and all were randomly assigned to one of the two condition groups.

F. PROCEDURES

Step One: The participant was provided with a mission brief (Appendix D) describing what was to be expected of him during the experiment and a map (Appendix E) showing the general layout of the virtual P.O.W. camp environment. The mission brief served two purposes. First, it provided general instructions in the form of a scenario to the participant for proper execution and completion of the experiment. The scenario itself consisted of two tasks: reconnaissance and rescue. The reconnaissance portion of the “mission” served the primary goal of this research – memorization, while the second task served to “drive” the participant into each of the four shacks in the virtual P.O.W. camp. The scenario was the same for all participants. The second purpose of the mission brief was not so obvious. The researcher worded the brief in an

effort to illicit an emotional response from the participant and hopefully boost their sense of presence.

Step Two: Upon acknowledgement of the tasks provided in the mission brief, the participant then practiced using the virtual P.O.W. camp environment. The training level VE was identical to the actual experiment VE, excluding the objects (and enemies) which would be presented during the experiment. In this training setting, the participant learned how to work the controls of the game (e.g., moved the mouse to gain the desired viewpoint, use the keyboard to maneuver within the virtual world, fire/reload/fix/switch weapons, etc.). The participant was also shown what the “mystery” box (mentioned in the brief) looked like and was given practice on picking it up. Once the participant felt comfortable with all of the aforementioned tasks, they were then directed to navigate the compound as depicted in the map (Appendix E). This was done to allow the participant to preview and pick out the various terrain and other obstacles he might have to overcome in the course of the actual experiment. Upon the participant’s exit of shack number 4, the researcher reiterated the primary (reconnaissance) and secondary (rescue) portions of his mission. The researcher felt that this “preview” of the virtual P.O.W. camp environment would provide the participant with a general knowledge of the virtual world and hence, minimize interference with the encoding of the desired objects during the actual experiment. As such, the training session was highly interactive, with the researcher answering any questions posed by the participants in an effort to increase their

comfort level and minimize their anxiety with respect to their surroundings in the virtual environment.

Step Three: When the participant indicated they were ready to continue, the researcher started the assigned condition for each participant. The researcher made it a point to remind the participant that this experiment was *not* timed and stressed the importance of memorizing all of the objects in each shack.

Step Four: After completing the experiment, the participants were administered a memory test (Appendix F) requiring them to recall particular objects in each shack.

Step Five: Twenty-four hours after completing the experiment, plus or minus 1 hour, each participant was contacted and asked to take another test (Appendix G). The purpose of this test was to help the researcher determine if there was an effect of retention interval on memory storage. The results of the tests administered in this and the previous step were the dependent measures used in the analysis of this experiment.

IV. ANALYSIS AND DISCUSSION

A. INTRODUCTION

The hypothesis:

The inducing of stress during a memorization task in a virtual environment will have no significant effect on the retrieval of the objects memorized.

Participants in this experiment were randomly assigned to one of two conditions, stress (encountered enemy) or no stress (did not encounter enemy). Both groups were administered the same memory tests immediately following the experiment and 24-hours later (Appendix F & G). The participants' correct responses to the questions served as the objective data points for study. The scores for both tests were averaged and compared with respect to time and conditions for the first analysis, then were aggregated by condition only for a second analysis. A statistical analysis using a two-sample t-test was conducted to test the experimental hypothesis.

B. ASSUMPTIONS

Although thirty (30) participants is not a large sample size, it is the defining sample size at which the Central Limit Theorem can be used [DEVO 00]. Assuming normality in the data is also justified as is depicted in figure 13 below. A power analysis of the data provided a **ß** value of 0.6791.

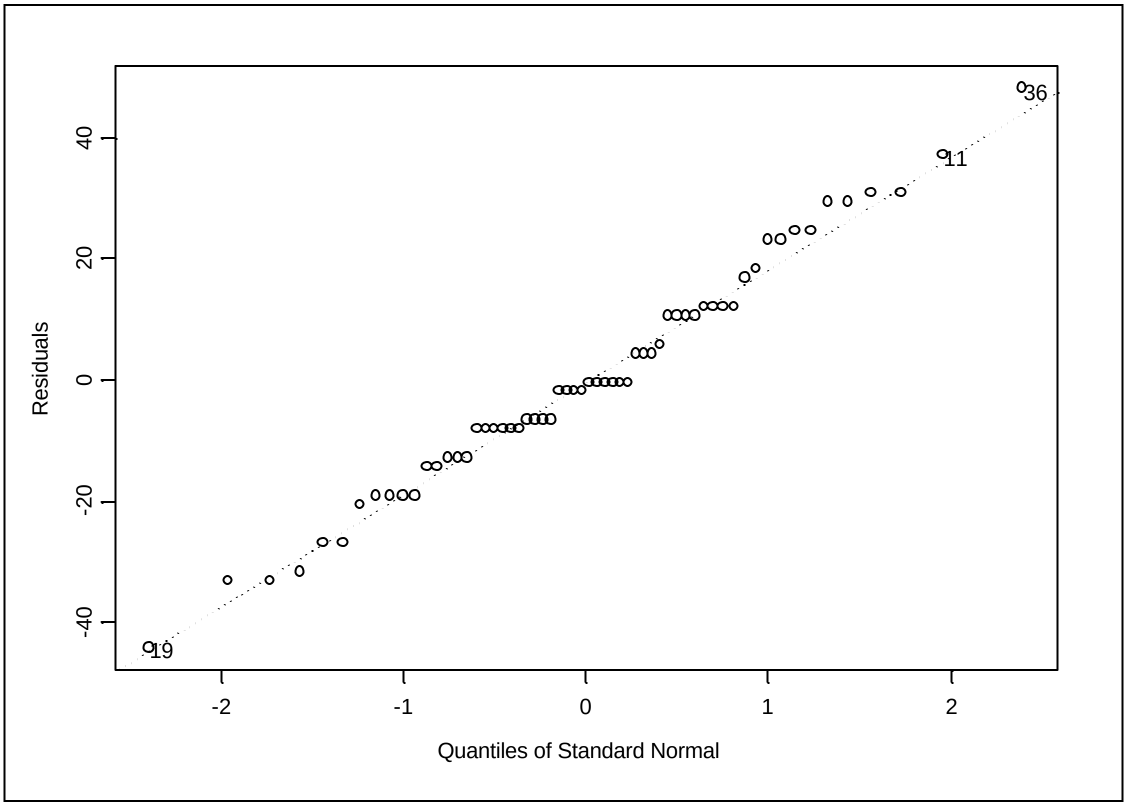

Figure 13. Data fits the Standard Normal.

C. RESULTS

The results of the data lend credibility to the claim that inducing stress ***does*** increase encoding and consequently retrieval of information memorized in a VE. Not only is the difference between the two conditions graphically distinct, but table 2 qualifies figure 14 with positive statistical results. Two-sample t-tests indicated statistically significant differences between treatment groups in both the memory test administered immediately after exposure to the VE (p=.05) and in testing 24 hours later (p=.04). More compelling is the statistical significance (p=.01) of the second analysis in which the

scores were aggregated (no distinction of time) by condition. The aggregation of the second analysis is done to reduce the recency effect (see Chapter II) of the immediate recall test [LOCK 00].

Table 2. Two-sample t-test results by condition, per test.

Test	Cond-1	Cond-2	Diff.	t-stat	Df	P-val
Immediate	71.67	59.58	12.09	1.7004	28	.0501
After 24Hrs.	54.17	44.17	10.00	1.7769	28	.0432

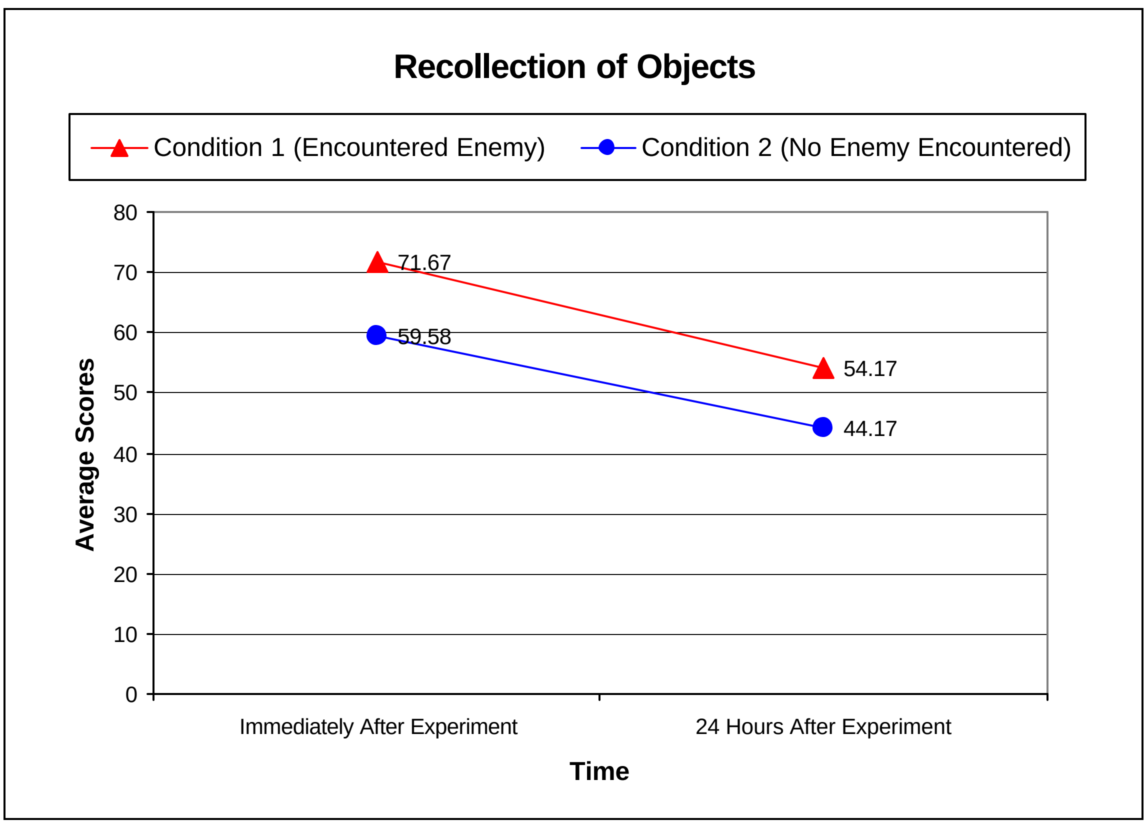

Figure 14. Scores averaged by condition, per test.

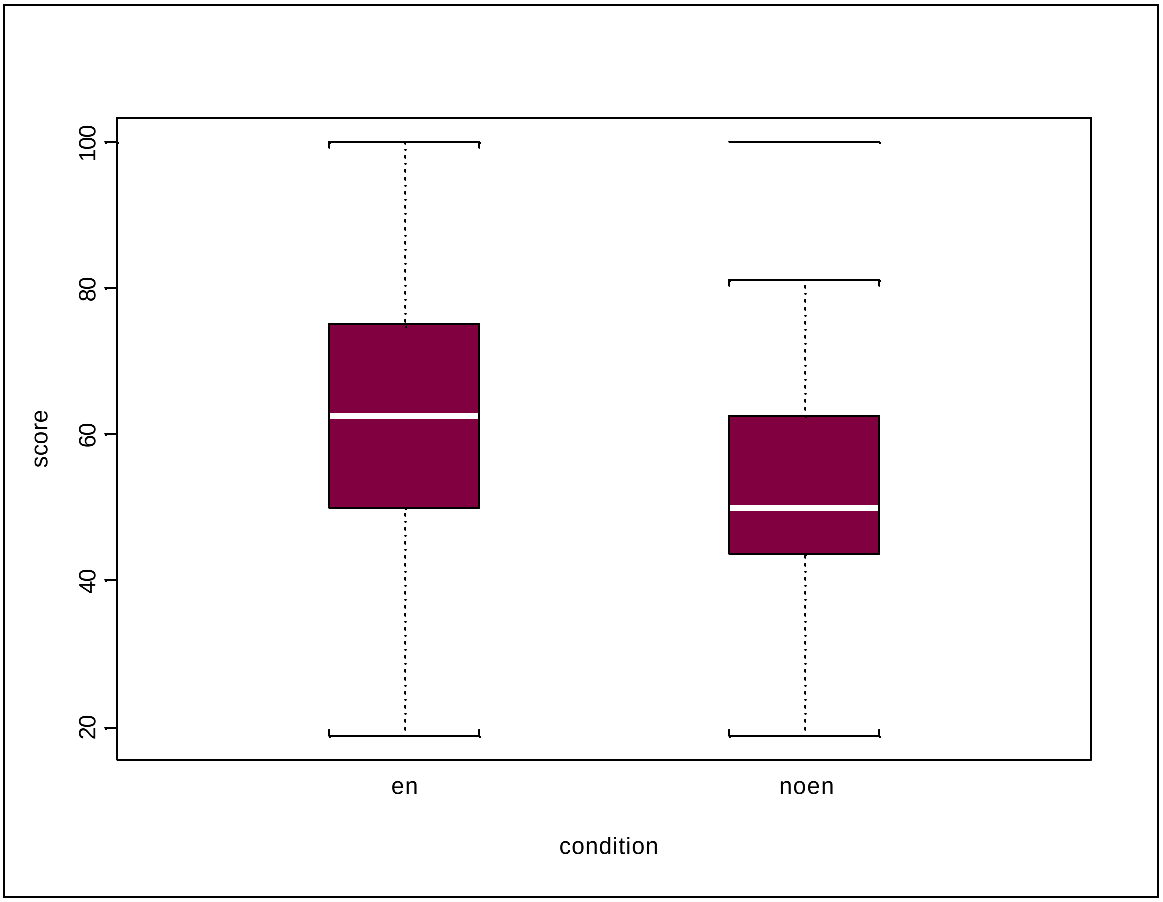

Figure 15. Box plot of aggregated scores.

Figure 15 and table 3 illustrate the results of the aggregated scores and substantiate the *alternative* hypothesis: that the true difference in means is greater than zero (0) with a p-value 0.0148.

Table 3. Two-sample t-test results, by condition, combined tests.

Test	**Cond-1**	**Cond-2**	Diff.	t-stat	Df	**P-val**
Combined	**62.92**	**51.88**	11.04	2.2297	58	**0.0148**

D. SUMMARY

The analysis of the data clearly shows that the participants in the “high-arousal” condition were better at encoding and recalling objects presented in the virtual environment. Although the difference in the means between the two conditions on the immediate recall test was only marginally significant, the delayed recall test (administered 24 hours later) and the results of the analysis of the aggregated scores lend solid credibility to the claim that emotional arousal (in this case, inducing stress) enhances memory storage.

The emotion aroused in this experiment, stress [a combination of fear and surprise (see figure 8)] was the simplest to implement and utilize as an exploratory tool in pursuit of the hypothesis. Other emotions, as illustrated in figure 8, could potentially be utilized as well. However, their effectiveness with respect to memory consolidation may not prove to be the same, as the emotion used here (stress) has been shown to release the endogenous hormones required to facilitate memory consolidation [CAHI 96] [CAHI 98] [LEDO 96] [MCGA 96] [MCGA 00].

The method used in this experiment to invoke the desired emotion (stress), by way of presence, was an emotionally captivating scenario set in a PC–based videogame. Although this game provided excellent video and audio representation of the virtual environment, it lacked (as do the majority of current similar games) the representation of other sensory modalities. The implementation of other sensory modalities in the virtual environment could further enhance the sense of presence,

emotional arousal and consequently, memory consolidation. In fact, research at Georgia Tech University has demonstrated that the addition of tactile and olfactory cues, in addition of the audio and video cues, increased both the participant’s sense of presence and their recollection of objects in a virtual environment [DINH 99]. These findings concur with those found by Sheridan, where he noted “the principle external determinants of presence is the existence of sensory information presented; that is, the greater the number of sensory inputs provided to different modalities, the greater the sense of presence” [SHER 92].

The implication of these results shows that emotional arousal in virtual environments for training is an important factor to consider when designing them. The impact that emotion has on an individual’s memory has long been documented. For example, you can recall a variety of information (e.g., place, time, environment, etc.) with great detail, the exact moment you heard about the September 11, 2001 attacks on the World Trade Center and the Pentagon, or when you first heard that President John F. Kennedy was assassinated, largely because of the emotional impact that the news had on you. Granted, the magnitude of the story itself may play a role in your recollection (also known as the novelty effect), but the research presented here lends credibility to its potential use in virtual environments and training.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The goal defined at the beginning of this thesis was to investigate the role emotional arousal plays in enhancing a trainee's memory for events that occurred during training in a virtual environment (VE). Since stress is a consequence of emotional arousal that can be induced in a relatively simple manner [LEDO 96], it was the emotion of choice for this research. The training virtual environment was set in a game that allowed participants to obtain a sense of presence, and thus fall prey to their emotions. The inducing of stress was done by means of their being attacked (shot at) by enemy in the virtual world. Thirty participants, half encountering enemy and the other half ***not*** encountering enemy, were tasked to memorize objects in this VE and were later asked to recall those same objects by means of written tests. Their correct responses to the questions posed in the tests were compared and found to be statistically significant, thus providing evidence that emotional arousal (in this case, the inducing of stress) enhances human memory. The results of this research identify the potential of using emotional arousal as an integral part of conducting training in virtual environments. Ultimately, as the capacity to use virtual environments as "tools" to train individuals increases and funds for conducting training in the field dwindles, the use of emotional arousal in VE training could prove extremely beneficial to all.

B. RECOMMENDATIONS

This study lends credibility to the importance of including emotional context when designing virtual environments used for training. In addition to stress, it is possible that developers of virtual environment training systems should include richer stories and more engaging characters that could further involve the trainee's emotions and consequently provide a more suitable context for intellectual and cognitive activity. Current virtual environment training systems, such as those under development by the Office of Naval Research [ONR 02a], lack the incorporation of a rich story and character depth which impair emotional immersion. This lack of emotional immersion poses a major barrier to conducting effective training.

Another important aspect in increasing emotional immersion in virtual environments is the realistic reproduction/representation of audio. The audio modality has received relatively little research attention despite evidence suggesting that audio fidelity has a more pronounced impact than visual fidelity on attention and memory, and that audio has a cross-over effect on visual evaluation [SHER 01]. However, recently completed research at the Naval Postgraduate School offered a solution to this void when Eric Krebs designed and implemented a sound system architecture for use in virtual environments [KREB 02]. Krebs' work and the results presented by this thesis offer virtual environment designers tools to build better trainers.

C. FUTURE WORK

This experiment illustrates that arousing emotion affects memory storage for objects memorized in a virtual environment. However, in order to validate the conclusion of this thesis with respect to *training* in virtual environments, a follow-on, similarly designed experiment might include an actual (virtually implemented) task that its participants are required to learn while their emotions are aroused. The experiment could run the gamut of not only emotions, but also the various intensity levels of those emotions.

Further validation can come from conducting the same or similar experiments while collecting physiological data. Studies have shown that physiological measurements taken while participants experience virtual environments provide an objective measure of presence [MEEH 02] [SAND 02].

Another approach to conducting similar research on memory in virtual environments for training might implement different types of effects (e.g., audio-video interference, dual-tasking, etc.) and account for their affect on memory consolidation/recollection. Yet another approach might be to vary the types of information required to be memorized and/or the different levels of emotion and study the correlation (if any) between type of information to be recalled and type of emotion induced.

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LIST OF REFERENCES

[ACCA 02] Accardo, S (2002). America's Army: Operations. Uncle Sam wants you … to play games. *GameSpy@E3.* Retrieved on September 13, 2002 from http://www.gamespy.com/e32002/pc/armyops/index.shtml.

[AMER 02] American Scientist. (n.d.). Retrieved September 20, 2002, from http://www.americanscientist.org/articles/01articles/Plutchik.html

[AMER 00] American Heritage® Dictionary of the English Language (4th Ed.). Houghton Mifflin Company.

[BADD 97] Baddeley, A.D. (1997). *Human memory: Theory and practice*. New York: Allyn & Bacon.

[BADD 00] Baddeley, A. (2000). Short-term and working memory. In E. Tulving & F.I.M. Craik (Eds.), *The oxford handbook of memory* (77-92). New York, NY: Oxford.

[BILB 02] Bilbruck, J. (2002). Multi-Purpose Supporting Arms Trainer Retrieved. *Naval Air Warfare Center, Live Fire Testing and Training Program website* [On-Line]. Retrieved September 10, 2002, from http://www.afams.af.mil/programs/projects/lftt/projects/mul_arm.htm

[BOWE 00] Bower, G.H. (2000). A brief history of memory research. In E. Tulving & F.I.M. Craik (Eds.), *The oxford handbook of memory* (3-32). New York, NY: Oxford.

[CAHI 96] Cahill, L., Haier, R. J., Fallon, J., Alkire, M.T., Tang, C., Keator, D., et al. (1996). Amygdala activity at encoding correlated with long-term, free recall of emotional information. *Proceedings of the National Academy of Sciences*, *93*, 8016-8021.

[CAHI 98] Cahill, L. & McGaugh, J.L. (1998). Mechanisms of emotional arousal and lasting declarative memory. Trends in Neurosciences, 21(7), 294-299.

[DEVO 00] Devore, J.L., (2000). Probability and statistics for engineering and the sciences (5^{th} ed.). Pacific Grove: Duxbury.

[DINH 99] Dinh, H.Q., Walker, N., Song, C., Kobayashi, A., Hodges, L.F., (1999). Evaluating the importance of multi-sensory input on memory and the sense of presence in virtual environments. Retrieved September 25, 2002, from http://www.cs.stevens-tech.edu/~quynh/smellorama.html.

[EICH 95] Eich, E. (1995). Mood as a mediator of place dependent memory. *Journal of Experimental Psychology: General, 124*, 293-308.

[HEAL 02] Healing Center Online, The. (n.d.). *Limbic System: The Center of Emotions.* Retreived September 15, 2002, from http://www.healing-arts.org

[HEIL 92] Heilig, M.L., “El Cine del Futuro: The Cinema of the Future”, Presence, 1(3), pp. 279-292.

[INST 02] Institute for Creative Technologies: Welcome to ICT (2002). Retrieved September 17, 2002, from http://www.ict.usc.edu/disp.php

[JOHN 98] Johnson, W.L., Rickel, J., Stiles, R., Munro, A. (1998). Integrating pedagogical agents into virtual environments. *Presence, 7(6)*, 523-546.

[KEPP 62] Keppel, G., & Underwood, B.J. (1962). Proactive inhibition in short-term retention of single items. *Journal of Verbal Learning and Verbal Behavior, 1*, 153-161.

[KOHA 00] Kohan, James (2000) MAPS Air Museum website [On-line]. Available: [http://www.mapsairmuseum.org/linktrainer.htm]

[KREB 02] Krebs, E., “An audio architecture integrating sound and live voice for virtual environments,” Master’s Thesis, Naval Postgraduate School, Monterey, California, September 2002.

[LEDO 92] LeDoux, J. E. (1992). Emotion and the Amygdala. In: Aggleton, J. P. (ed), *The Amygdala: Neurobiological Aspects of Emotion, Memory and Mental Dysfunction* (pp. 339-351). New York: Wiley-Liss.

[LEDO 96] LeDoux, J., (1996). The emotional brain: The mysterious underpinnings of emotional life. New York, NY: Simon & Schuster.

[LOCK 99] Lockheed Martin Missiles & Space. (1999, April). Virtual Environments for Training Final Report. (Prepared for Office of Naval Research Contract N00014-95-C-0179). Sunnyvale, CA: Submitted by: Randy Stiles.

[LOCK 00] Lockhart, R. S. (2000). Methods of memory research. In E. Tulving & F.I.M. Craik (Eds.), *The oxford handbook of memory* (43-58). New York, NY: Oxford.

[MACE 01] Macedonia, Michael R. & Rosenbloom, Paul S. (2001). Entertainment Technology and Virtual Environments for Training and Education [Electronic Version]. In Devlin, M., Larson, R., Meyerson, J. (Eds.), *The internet and the university: 2000 Forum* (79-95). Boulder, CO: Educause.

[MCGA 96] McGaugh, J.L., Cahill, L., & Roozendaal, B. (1996). Involvement of the amygdale in memory storage: Interactions with other brain systems. *Proceedings of the National Academy of Sciences, 93,* 13508-13514.

[MCGA 00] McGaugh, J.L. (2000, Autumn). Research shows the role of emotions and stress in forming long-lasting memories. Brain Frontiers, (2-3).

[MEEH 02] Meehan, M., Insko, B., Whitton, M., Brooks, F.P., Jr., (2002). Physiological measures of presence in stressful virtual environments. *ACM Transactions on Graphics: Proceedings of ACM SIGGRAPH 2002, 23(3)*, 645-652.

[MICR 02] Micro-simulator Systems for Immersive Learning Environments (2002). Retrieved September 9, 2002, from https://www.cnet.navy.mil/microsim/

[ONR 02] Office of Naval Research (2002). Retrieved September 7, 2002, from http://www.onr.navy.mil/sci_tech/personnel/cnb_sci/342/default.htm

[ONR 02a] Office of Naval Research (2002). RetrievedSeptember 7, 2002, from http://www.onr.navy.mil/sci%5Ftech/personnel/cnb%5Fsci/342%5Forig/addlcap/virenv/virenv11.htm

[SAND 02] Sanders, R.D. & Scorgie, M.A., “The effect of sound delivery methods on a user’s sense of presence in a virtual environment,” Master’s Thesis, Naval Postgraduate School, Monterey, California, March 2002.

[SHER 92] Sheridan, T.B., “Musings on telepresence and virtual presence,” *Presence: Teleoperators and Virtual Environments*, 1, pp. 120-125, 1992.

[STRA 19] Stratton, G. M. (1919) *Psychological Review, 26*, 474-486.

[TAN 01] Tan, D.S., Stefanucci, J.K., Proffitt, D.R. &Pausch, R. (2001) The Infocockpit: Providing Location and Place to Aid Human Memory. Workshop on Perceptive User Interfaces 2001, Orlando, Florida.

[TULV 72] Tulving, E., (1972). Episodic and semantic memory. In T.R. Dixon & D.L. Horton (Eds.), *Organization of memory* (381-403). New York: Oxford University Press.

[TULV 83] Tulving, E., (1983). *Elements of episodic memory*. Oxford: Oxford University Press.

[TULV 00] Tulving, E., (2000). Concepts of memory. In E. Tulving & F.I.M. Craik (Eds.), *The oxford handbook of memory* (33-43). New York, NY: Oxford.

[VIAN 01] Vianna, M.R.M., Szapiro, G., McGaugh, J.L.,Medina, J.H., & Izquierdo, I. (2001). Retrieval of memory for fear-motivated training initiates extinction requiring protein synthesis in the rat hippocampus. *Proceedings of the National Academy of Sciences, 93 (21),* 12251-12254.

[WICK 00] Wickens, C.D., & Hollands, J.G., (2000). *Engineering psychology and human performance* (3rd ed.). Upper Saddle River, NJ: Prentice-Hall.

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APPENDIX A: RAW DATA

Participant Number	Condition 1=Enemies 2=No Enemies	Age	Sex	Service	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11	1.12	1.13	1.14	1.15	1.16
1	1	35	M	USN	1	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1
3	1	30	M	USN	1	1	1	0	1	0	0	0	0	0	0	0	0	1	0	0
5	1	34	M	USMC	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	0
7	1	31	M	USN	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	1
10	1	32	M	USA	1	1	1	0	1	1	1	1	1	0	0	0	1	0	0	0
11	1	27	M	USN	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1
13	1	33	M	USN	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1
15	1	37	M	USN	1	1	1	1	1	0	1	1	0	0	1	0	0	1	0	1
17	1	37	M	USMC	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	0
19	1	35	M	USN	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
21	1	32	M	USMC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	31	M	USN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
25	1	29	M	USN	1	1	1	0	0	1	1	1	1	0	0	0	0	1	0	1
27	1	30	M	USN	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1
29	1	28	M	USN	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
2	2	31	M	USN	0	0	0	0	0	1	1	1	1	1	0	1	0	1	1	1
4	2	33	M	USMC	1	1	1	1	1	0	1	1	0	0	1	0	0	0	0	0
8	2	37	F	USN	1	0	1	1	0	1	0	1	0	0	0	0	0	0	0	1
9	2	33	M	USN	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	1
12	2	26	M	USN	1	1	1	1	1	0	1	1	0	0	0	0	0	0	1	1
14	2	39	M	USN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	2	43	M	USA	1	1	1	1	1	0	1	1	0	1	1	0	0	0	0	1
18	2	36	M	USA	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1
20	2	30	F	CIV	1	1	1	0	1	0	1	1	1	0	0	1	0	1	0	1
22	2	29	M	USN	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1
24	2	24	M	CIV	1	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0
6	2	31	M	USMC	1	1	1	1	1	1	1	0	1	0	1	0	0	1	1	1
28	2	24	M	USCG	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0
30	2	36	M	USN	1	1	0	1	0	1	1	1	0	1	0	0	0	0	0	1
32	2	36	M	USA	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Figure 16. Appendix A: Raw Data – Participants' answers to Test #1

INFORMATION:

A "1" in the cell indicates a correct answer; a "0" indicates an incorrect answer.

Participant Number	Condition 1=Enemies 2=No Enemies	Age	Sex	Service	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	2.11	2.12	2.13	2.14	2.15	2.16
1	1	35	M	USN	1	1	0	1	0	1	0	1	0	0	1	0	0	0	0	1
3	1	30	M	USN	1	1	1	0	0	0	0	1	0	0	0	1	1	1	0	0
5	1	34	M	USMC	1	1	0	1	0	0	0	0	0	1	1	0	0	1	0	1
7	1	31	M	USN	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0
10	1	32	M	USA	0	1	0	0	0	0	1	0	1	1	0	0	1	1	0	1
11	1	27	M	USN	0	1	0	1	0	0	0	0	1	1	0	1	1	1	1	1
13	1	33	M	USN	0	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1
15	1	37	M	USN	1	1	0	1	0	0	1	0	1	1	1	1	1	0	1	0
17	1	37	M	USMC	0	1	0	1	1	0	0	0	1	1	1	0	1	0	1	0
19	1	35	M	USN	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
21	1	32	M	USMC	1	1	1	1	0	1	0	1	1	0	0	1	1	1	1	1
23	1	31	M	USN	0	1	0	1	1	1	0	1	1	1	1	1	0	0	1	0
25	1	29	M	USN	0	1	0	0	0	0	0	0	1	1	1	0	1	1	1	1
27	1	30	M	USN	1	1	1	1	0	1	0	1	1	1	1	1	1	0	0	1
29	1	28	M	USN	1	1	0	0	0	0	1	1	1	1	0	1	1	1	0	1
2	2	31	M	USN	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1
4	2	33	M	USMC	0	0	0	0	0	0	1	0	0	1	1	1	0	1	0	0
8	2	37	F	USN	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0
9	2	33	M	USN	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0
12	2	26	M	USN	0	0	0	0	1	0	0	0	1	1	1	1	1	1	0	0
14	2	39	M	USN	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0
16	2	43	M	USA	0	1	1	0	0	0	0	0	0	0	1	1	1	1	0	1
18	2	36	M	USA	0	0	1	0	0	1	0	1	0	0	0	1	1	1	0	1
20	2	30	F	CIV	1	1	0	1	1	1	0	1	0	1	1	0	0	0	0	0
22	2	29	M	USN	1	1	0	1	0	0	0	0	1	1	1	0	1	1	1	1
24	2	24	M	CIV	1	0	0	0	0	0	0	0	1	1	0	1	1	1	1	0
6	2	31	M	USMC	1	1	0	0	0	0	1	0	0	1	0	1	1	1	0	0
28	2	24	M	USCG	1	1	1	0	0	0	1	1	1	0	1	1	1	0	1	0
30	2	36	M	USN	0	0	1	0	1	1	0	1	1	1	1	1	0	0	0	0
32	2	36	M	USA	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0

Figure 17. Appendix A: Raw Data – Participants' answers to Test #2

INFORMATION:

A "1" in the cell indicates a correct answer; a "0" indicates an incorrect answer.

APPENDIX B: EXPERIMENT PROTOCOL

I. Consent forms
   A. Have participant read and sign consent forms.
   B. Assign participant a subject ID and Condition.
   C. Condition values:
      1. 1 – Enemy
      2. 2 – No Enemy

II. Introduction
   A. Have the participant read the mission brief, and ask them to verify their understanding of the required route (using map) to take in the VE.

III. America's Army℠: Operations Practice
   A. Logon to computer in the Multimedia Lab.
      1. Start America's Army℠: Operations (research designed build) by double-clicking on the America's Army℠: Operations shortcut on the desktop.
      2. Hit tab and type in “tmap” (for training map) (This opened up the research designed level of HQ_Raid)
      3. Lead the participant through the various functions of the game (e.g., navigation, weapon use, etc.)
      4. Once the participant expressed feeling comfortable with all aspects of the virtual environment, we would go to step VI.

IV. America's Army℠: Operations
   A. Hit tab and type in the assigned condition map:
      1 – “emap”
      2 – “nmap”
   B. When the participant is finished, direct him/her to complete the Immediate Recall Exam.
   C. Coordinate administration of the delayed recall follow-up test
   D. Inform participant that he/she is not allowed to make paper notes of the environment.

V. Follow-up test
   A. Administer the delayed recall test to the participant

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APPENDIX C: CONSENT FORMS

GENERAL:

The forms in the appendix appear in the same format used for the experiment and do not follow the standard thesis format utilized in this thesis. This appendix consists of three documents: Consent Form, Minimal Risk Consent Statement, and the Privacy Act Statement. Each participant is required to read and sign these documents prior to participating in the experiment.

PARTICIPANT CONSENT FORM

1. **Introduction.** You are invited to participate in a study that attempts to measure a person's ability to commit to memory and subsequently recall objects presented in a first-person shooter virtual environment/game. This research is aimed at improving individuals' memory recollection when utilizing virtual environments as training devices. Your recorded data will be used in an effort to determine which sounds and/or scenarios should be considered for inclusion in virtual environment training systems.

2. **Background Information.** Data is being collected by the Naval Postgraduate School's Human System's Integration Laboratory for use in developing virtual environments.

3. **Procedures.** If you participate in this study, the researcher will ask you complete two short questionnaires and two short recall tests. You will first be asked to fill out a short questionnaire, followed by approximately 15 minutes of playing a game (see attached sheet titled "Memory Experiment" for game scenario/procedures). Upon completion of the game, you will be asked to take a short test asking you to recall the objects presented to you during the game. Exactly 24 hours later (the retention interval), you will be asked to fill out another questionnaire and take another short test asking you to again recall the items presented to you in the virtual environment the previous day. This entire evolution, not including the retention interval, will take approximately 30 minutes.

4. **Risks and Benefits.** The questionnaires, experiment, and tests involve no risks to individuals, however, IF YOU FEEL UNCOMFORTABLE WITH THE INTERVIEW OR THE GAME SCENARIO AT ANY TIME, PLEASE INFORM THE EXPERIMENTER AT ONCE AND DO NOT PROCEED ANY FURTHER. The benefits to the participants will be to contribute to current research in advancing virtual environments and in human-computer interaction.

5. **Compensation.** No tangible reward will be given. A copy of the results will be available to you at the conclusion of the experiment.

6. **Confidentiality.** The records of this study will be kept confidential. No information will be publicly accessible which could identify you as a participant.

7. **Voluntary Nature of the Study.** If you agree to participate, you are free to withdraw from the study at any time without prejudice. You will be provided a copy of this form for your records.

8. **Points of Contact.** If you have any further questions or comments after the completion of the study, you may contact the research supervisor, Dr. Russell Shilling (831) 656-2543 shilling@cs.nps.navy.mil.

9. **Statement of Consent.** I have read the above information. I have asked all questions and have had my questions answered. I agree to participate in this study.

-- ---------------------------

Participant's Signature Date

-- ---------------------------

Researcher's Signature Date

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
MINIMAL RISK CONSENT STATEMENT

Participant:

VOLUNTARY CONSENT TO BE A RESEARCH PARTICIPANT IN: Measuring Memory Encoding and Retrieval in a Virtual Environment.

1. I have read, understand and been provided the "Participant Consent Form" that provides the details of the below acknowledgments.

2. I understand that this project involves research. An explanation of the purposes of the research, a description of procedures to be used, identification of experimental procedures, and the extended duration of my participation have been provided to me.

3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonably foreseeable risks or discomforts to me.

4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.

5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.

6. I have been informed of any compensation and/or medical treatments available if injury occurs and if so, what they consist of, or where further information may be obtained.

7. I understand that my participation in this project is voluntary; refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

8. I understand that the individual to contact should I need answers to pertinent questions about the research is Professor Russell Shilling, Principal Investigator, and about my rights as a research participant or concerning a research related injury. A full and responsive discussion of the elements of this project and my consent has taken place.

Signature of Principal Investigator Date Signature of Volunteer Date

Signature of Witness Date

PRIVACY ACT STATEMENT
NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
PRIVACY ACT STATEMENT

1. Authority: Naval Instruction

2. Purpose: MEASURING MEMORY ENCODING AND RETRIEVAL IN A VIRTUAL ENVIRONMENT

3. Use: Response data will be used for statistical analysis by the Departments of the Navy and Defense, and other U.S. Government agencies, provided this use is compatible with the purpose for which the information was collected. The Naval Postgraduate School in accordance with the provisions of the Freedom of Information Act may grant use of the information to legitimate nongovernmental agencies or individuals.

4. Disclosure/Confidentiality:

a. I have been assured that my privacy will be safeguarded. I will be assigned a control or code number, which thereafter will be the only identifying entry on any of the research records. The Principal Investigator will maintain the cross-reference between name and control number. It will be decoded only when beneficial to me or if some circumstances, which are not apparent at this time, would make it clear that decoding would enhance the value of the research data. In all cases, the provisions of the Privacy Act Statement will be honored.

b. I understand that a record of the information contained in this Consent Statement or derived from the experiment described herein will be retained permanently at the Naval Postgraduate School or by higher authority. I voluntarily agree to its disclosure to agencies or individuals indicated in paragraph 3 and I have been informed that failure to agree to such disclosure may negate the purpose for which the experiment was conducted.

c. I also understand that disclosure of the requested information is voluntary.

____
Signature of Volunteer   Print Name,   Grade/Rank,   DOB   Date

____
Signature of Witness   Date

APPENDIX D: MISSION BRIEF

GENERAL:

The form in this appendix appears in the same format used for the experiment and does not follow the standard thesis format utilized in this thesis. This appendix consists of one document: a detailed description of instructions for the successful completion of the (memory task) “mission.” Each participant is asked to read and ask questions of the researcher if the instructions are not understood. The brief is followed by a period of training in the virtual P.O.W. camp environment.

Memory Experiment

Introduction: This experiment will examine your ability to remember certain aspects and objects presented in a virtual environment (i.e. first-person shooter game).

Situation: You find yourself on a solo Prisoner-of-War (POW) rescue/reconnaissance mission in a virtual POW camp. This camp, *which may or may not be guarded* during your mission, consists of four shacks surrounding a POW cell (which is currently holding 2 of your captured comrades). Each shack is clearly and plainly numbered on its interior walls. Inside each shack, you'll find miscellaneous furniture and objects that one would typically expect to see in such a place. However, each shack will ***also*** contain a few distinctly *atypical* objects, one of which is a "mystery" box, which, according to our intelligence reports, contains a key to the POW cell.

Your Mission: Our intelligence reports confirm the existence of four "mystery" boxes, one box in each shack, each box containing a key. Unfortunately, the intel guys are unable to ascertain which specific box contains the *required* key. Therefore, you must navigate through the ***REAR DOORS ONLY*** (see map) of each shack in the POW camp and collect ALL four "mystery" boxes BEFORE attempting to release the POW's and without being detected by any guards. Additionally, you'll need to report back any *atypical* objects you may find ***and*** in which shack you saw them. Your mission is complete when you have collected ALL four boxes.

Enemy: If you encounter any enemy guards, kill them before they kill you, and then continue your collection of the "mystery" boxes and reconnaissance of the shacks. You may shoot at anything you see, but be sure you kill any and all enemy before they kill you.

Training: You'll be placed in a mock-up replica of the actual POW camp (experiment) setting. In this location, you will learn how to navigate through the virtual POW camp world, get a feel for the layout of the POW camp, and you'll also learn and practice the selection and firing of your weapons and equipment. There are replicas of the shacks with the numbers painted on their interior walls matching the numbers you will see in the actual experiment POW camp. You'll also find a replica of the "mystery" box that you actually need to acquire in the experiment. You'll get to practice picking up this box. At any time during this training session, please feel free to ask any questions.

Remember: This is **not** a timed event. You will answer a set of questions (reconnaissance report) immediately following the experiment and another set of questions (reconnaissance report confirmation) in 24 hours. The questions will be about those unusual objects you saw in each shack. Take your time.

APPENDIX E: MAP OF ROUTE IN THE VIRTUAL ENVIRONMENT

GENERAL:

The form in this appendix appears in the same format used for the experiment and do not follow the standard thesis format utilized in this thesis. This appendix consists of one document: a simple introductory (background) questionnaire. Each participant is asked to fill one out prior to participating in the experiment.

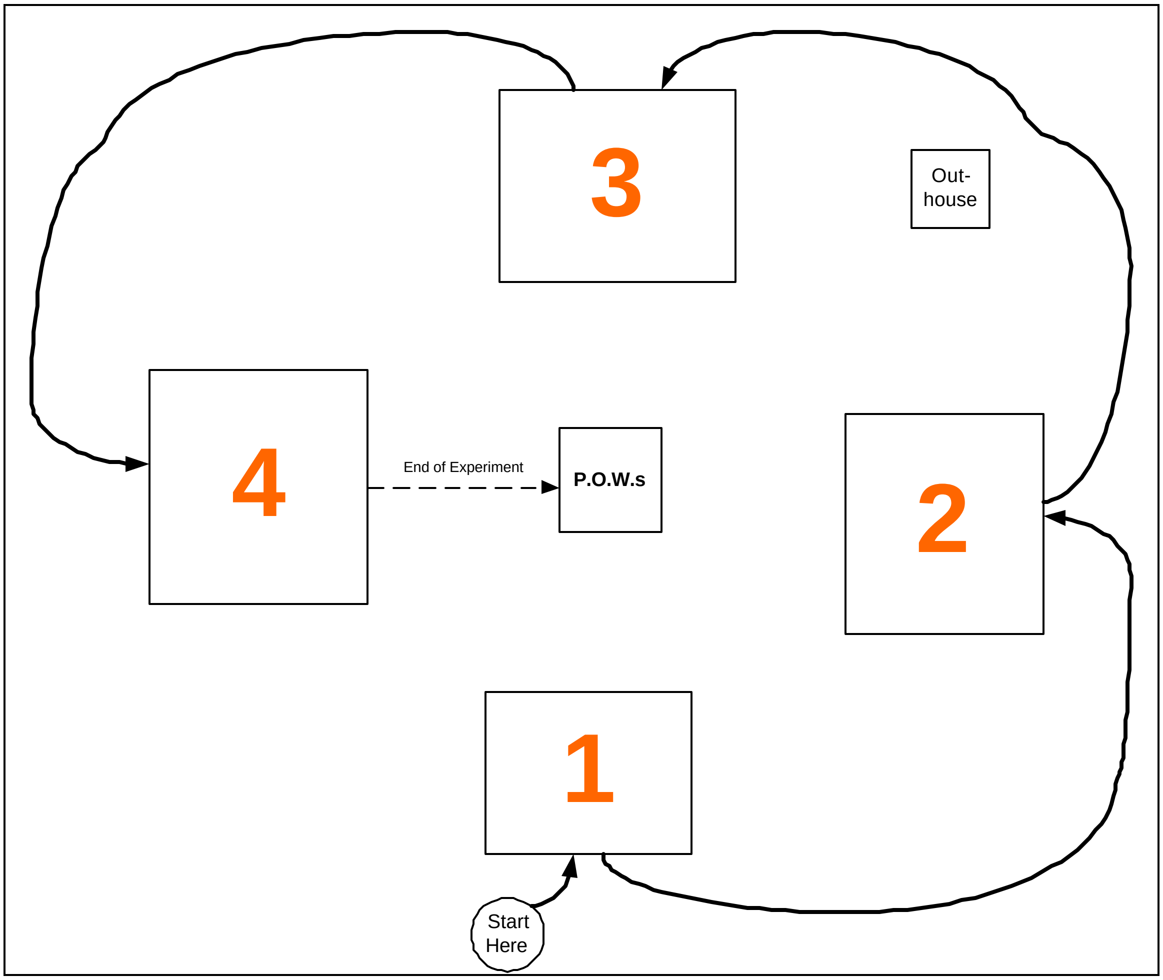

Figure 18. Appendix E: Map of the route the participants were required to follow in the VE.

APPENDIX F: IMMEDIATE RECALL TEST

GENERAL:

The forms in this appendix appear in the same format used for the experiment and do not follow the standard thesis format utilized in this thesis. This appendix consists of two documents: the "(Immediate) Reconnaissance Report" given to the participants immediately after their completion of the memorization tasks in the VE followed by the same form with the correct answers marked. Each participant is asked to take the test and answer every question to the best of their ability.

(Immediate) Reconnaissance Report

Name: ____________________________

1. Which ONE of the following objects was in shack 1?

Magazines	House Plant	Vending Machine	Coffee Cup

2. Which ONE of the following objects was in shack 1?

Fire Extinguisher	Water Fountain	Computer	Megaphone

3. Which ONE of the following objects was in shack 2?

Microwave	Vending Machine	Big Screen TV	House Plant

4. Which ONE of the following objects was in shack 2?

Coffee Pot	Blueprints	Computer	Flame on oil drum

5. Which ONE of the following objects was in shack 3?

Big Screen TV	Flame on oil drum	House Plant	Fire Extinguisher

6. Which ONE of the following objects was in shack 3?

Computer	Refrigerator	Flame on oil drum	Microwave

7. Which ONE of the following objects was in shack 4?

Vending Machine	Magazines	Fire Extinguisher	Big Screen TV

8. Which ONE of the following objects was in shack 4?

Blueprints	Coffee Pot	Megaphone	Refrigerator

9. Which shack contained two (2) cots?

1 2 3 4

10. Which shack had a lantern that was knocked over and unlit?

1 2 3 4

11. Which shack had a lit lantern on the floor?

1 2 3 4

12. Which shack had a cot that leaned upright against the wall?

1 2 3 4

13. Which shack had a lantern that was on an oil drum?

1 2 3 4

14. Which shack had a cot that was knocked over?

1 2 3 4

15. Which shack had a lit lantern on the table?

1 2 3 4

16. Which shack had a book on the table?

1 2 3 4

(Immediate) Reconnaissance Report

Name: ________________________________

1. Which ONE of the following objects was in <u>shack 1</u>?

Magazines	House Plant	Vending Machine	Coffee Cup

2. Which ONE of the following objects was in <u>shack 1</u>?

Fire Extinguisher	Water Fountain	Computer	Megaphone

3. Which ONE of the following objects was in <u>shack 2</u>?

Microwave	Vending Machine	Big Screen TV	House Plant

4. Which ONE of the following objects was in <u>shack 2</u>?

Coffee Pot	Blueprints	Computer	Flame on oil drum

5. Which ONE of the following objects was in <u>shack 3</u>?

Big Screen TV	Flame on oil drum	House Plant	Fire Extinguisher

6. Which ONE of the following objects was in <u>shack 3</u>?

Computer	Refrigerator	Flame on oil drum	Microwave

7. Which ONE of the following objects was in <u>shack 4</u>?

Vending Machine	Magazines	Fire Extinguisher	Big Screen TV

8. Which ONE of the following objects was in <u>shack 4</u>?

Blueprints	Coffee Pot	Megaphone	Refrigerator

9. Which shack contained two (2) cots?

1 2 3 4

10. Which shack had a lantern that was knocked over and unlit?

1 2 3 4

11. Which shack had a lit lantern on the floor?

1 2 3 4

12. Which shack had a cot that leaned upright against the wall?

1 2 3 4

13. Which shack had a lantern that was on an oil drum?

1 2 3 4

14. Which shack had a cot that was knocked over?

1 2 3 4

15. Which shack had a lit lantern on the table?

1 2 3 4

16. Which shack had a book on the table?

1 2 3 4

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APPENDIX G: DELAYED RECALL TEST

GENERAL:

The forms in this appendix appear in the same format used for the experiment and do not follow the standard thesis format utilized in this thesis. This appendix consists of two documents: the “Reconnaissance Report (Confirmation)” given to the participants 24 hours (plus or minus 1 hour) after their completion of the memorization tasks in the VE followed by the same form with the correct answers marked. Each participant is asked to answer every question to the best of their ability.

Reconnaissance Report (Confirmation)

Name: ___________________________________

1. **How many hours of sleep did you have last night?**
   less than 4 4 to 6 6 to 8 more than 8

2. **If you drink coffee, estimate how many cups (8oz/cup) have you had so far today?**
   2 or less 3 to 5 6 or more

---

1. Which ONE of the following was in shack 1?

Lit lantern on drum Lit lantern on floor Unlit lantern Lit lantern on table

2. Which ONE of the following was in shack 1?

Cot leaning upright on wall 2 cots Properly set-up cot Cot knocked over on floor

3. Which ONE of the following was in shack 2?

Lit lantern on drum Lit lantern on floor Unlit lantern Lit lantern on table

4. Which ONE of the following was in shack 2?

Cot leaning upright on wall 2 cots Properly set-up cot Cot knocked over on floor

5. Which ONE of the following was in shack 3?

Lit lantern on drum Lit lantern on floor Unlit lantern Lit lantern on table

6. Which ONE of the following was in shack 3?

Cot leaning upright on wall 2 cots Properly set-up cot Cot knocked over on floor

7. Which ONE of the following was in shack 4?

Lit lantern on drum Lit lantern on floor Unlit lantern Lit lantern on table

8. Which ONE of the following was in shack 4?

Cot leaning upright on wall 2 cots Properly set-up cot Cot knocked over on floor

9. Which shack contained a set of blueprints?

1 2 3 4

10. Which shack had a computer?

1 2 3 4

11. Which shack contained a megaphone?

1 2 3 4

12. Which shack had a flame coming out of a drum?

1 2 3 4

13. Which shack had a big screen TV?

1 2 3 4

14. Which shack had a vending machine?

1 2 3 4

15. Which shack had a microwave/toaster oven unit?

1 2 3 4

16. Which shack had a refrigerator?

1 2 3 4

Reconnaissance Report (Confirmation)

Name:________________________________

1. **How many hours of sleep did you have last night?**
   less than 4 4 to 6 6 to 8 more than 8

2. **If you drink coffee, estimate how many cups (8oz/cup) have you had so far today?**
   2 or less 3 to 5 6 or more

---

1. Which ONE of the following was in shack 1?

Lit lantern on drum Lit lantern on floor Unlit lantern Lit lantern on table

2. Which ONE of the following was in shack 1?

Cot leaning upright on wall 2 cots Properly set-up cot Cot knocked over on floor

3. Which ONE of the following was in shack 2?

Lit lantern on drum Lit lantern on floor Unlit lantern Lit lantern on table

4. Which ONE of the following was in shack 2?

Cot leaning upright on wall 2 cots Properly set-up cot Cot knocked over on floor

5. Which ONE of the following was in shack 3?

Lit lantern on drum Lit lantern on floor Unlit lantern Lit lantern on table

6. Which ONE of the following was in shack 3?

Cot leaning upright on wall 2 cots Properly set-up cot Cot knocked over on floor

7. Which ONE of the following was in shack 4?

Lit lantern on drum Lit lantern on floor Unlit lantern Lit lantern on table

8. Which ONE of the following was in shack 4?

Cot leaning upright on wall 2 cots Properly set-up cot Cot knocked over on floor

9. Which shack contained a set of blueprints?

1 2 3 4

10. Which shack had a computer?

1 2 3 4

11. Which shack contained a megaphone?

1 2 3 4

12. Which shack had a flame coming out of a drum?

1 2 3 4

13. Which shack had a big screen TV?

1 2 3 4

14. Which shack had a vending machine?

1 2 3 4

15. Which shack had a microwave/toaster oven unit?

1 2 3 4

16. Which shack had a refrigerator?

1 2 3 4

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APPENDIX H: CONTENTS OF SHACKS IN VE

Figure 19. Appendix H: Contents of Shack 1.

List of items that were tested
(Clockwise from lower left corner):

- Flame on oil drum
- Computer
- House plant
- Lit lamp on floor
- Knocked-over cot

Figure 20. Appendix H: Contents of Shack 2.

List of items that were tested
(Clockwise from lower left corner):

- Knocked-over, unlit lantern
- Megaphone
- Coffee pot
- Vending machine
- Cot leaning upright against the wall

Figure 21. Appendix H: Contents of Shack 3.

List of items that were tested
(Clockwise from lower left corner):

- Refrigerator
- Magazines on table
- Book on table
- Big Screen TV
- Lit lantern on oil drum
- One properly set-up cot

Figure 22. Appendix H: Contents of Shack 4.

List of items that were tested
(Clockwise from lower left corner):

- Lit lantern on table
- Microwave
- Blueprints
- Fire Extinguisher
- Water fountain
- Two cots

APPENDIX I: EQUIPMENT SPECIFICATIONS

Alienware Majestic 12 (1 used):

CPU	Intel Pentium 4 1.8GHz
RAM	512MB
Hard drive	40GB
Operating System	Windows XP

Genelec 1031A Bi-amplified Speaker (Five used):

Free field frequency response of system:	48 Hz - 22 kHz (± 2 dB)
Harmonic distortion at 90 dB SPL @ 1m on axis: Freq: 50...100 Hz > 100 Hz	 < 1% < 0.5%
Drivers: Bass Treble	 210 mm (8") cone 25 mm (1") metal dome
Bass amplifier output power with an 8Ohm load:	120 W
Treble amplifier output power with an 8Ohm load: Long term output power is limited by driver unit protection circuitry.	120 W
Signal to Noise ratio, referred to full output:	Bass > 100 Db Treble > 100 dB

Genelec 1094A Active Subwoofer System (1 used):

Free field frequency response of system (± 2.5dB):	29 - 80 Hz
Harmonic distortion at 100 dB SPL @ 1m on axis in half space (30...100 Hz):	< 3%
Drivers:	385 mm (15")
Short term amplifier output power:	400 W (8 Ohm)
Signal to Noise ratio, referred to full output:	> 100 dB

Monitor MultiSync® LCD1830™Specifications Monitor

LCD Module

Diagonal:	18.1 inch
Viewable Image Size:	18.1 inch
Native Resolution (Pixel Count):	1280x1024

Active matrix; thin film transistor (TFT) liquid crystal display (LCD); 0.28 mm dot pitch; 200cd/m2 white luminence; 300:1 contrast ratio, typical

Input Signal

Video:	ANALOG 0.7 Vp-p/75 Ohms
Sync:	Separate sync. TTL Level Horizontal sync. Positive/Negative Vertical sync. Positive/Negative Composite sync. Positive/Negative Sync on Green (Video 0.7p-p and Sync 0.3V p-p)

Display Colors

Analog input:	16,777,216

Viewing Angle

Left/Right:	±80°
Up/Down:	±80°

Synchronization Range

Horizontal:	24 kHz to 82 kHz Automatically
Vertical:	55 Hz to 85 Hz Automatically

Resolution Used

1024 x 768 at 75 Hz

Active Display Area

Horizontal:	359 mm/14.1 inches Dependent upon signal timing used,
Vertical:	287 mm/11.3 inches and does not include border area.

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